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LOSS OF PRESSURE CAUSED BY METERS IN FACTORY FIRE SUPPLIES.

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[*Read Sept. 8, 1897.*]

OBJECT.

The tests described in this paper were made under the auspices of the Factory Mutual Fire Insurance Companies, with the generous cooperation of the Naumkeag Cotton Mills, and the Salem (Mass.) Water Works, and others named below. Their main object was to determine the loss of pressure caused by meters, especially with reference to their use on fire service pipes, and to determine the safest form of meter for this kind of work. The work was all carried on under the general direction of Mr. John R. Freeman.

In the matter of water meters on large fire pipes the interests of the insurance companies and water departments sometimes seem to conflict.

Commonly when starting anew the pipe systems can be so arranged as to provide a small separate pipe into the mill yard for its regular supply for domestic and manufacturing purposes which can be metered while a separate pipe is run for fire purposes alone, which is so simply arranged and with so small possibility of draft that no meter is needed, and more than nine-tenths of the factories insured

in the Factory Mutuals thus find no necessity for use of meters. But there are places where meters on fire supplies appear to be a necessity. We have, therefore, thought that to lay our data before you, thereby making clear the causes of our objections to meters, might encourage the production of some sort of a metering device capable of thoroughly guarding the interests of Water Departments but free from the impairment of fire protection presented in greater or less degree, by all existing meters.

It may be well for the sake of completeness, to briefly restate the insurance companies objections to meters on fire pipes—these are:

1st. Meters obstruct the flow of water, thus lessening the efficiency of fire streams. Many common types of meter that are excellent for accuracy of metering so obstruct the flow as to reduce the pressure under ordinary fire conditions more than one-half.

2nd. The moving parts of many meters in common use, may become so stuck by a stick or stone coming along in the water, as to absolutely prevent the flow of enough water to be of any service whatever for fire work. Moreover, when meters remain idle for long periods, as is often the case on fire pipes, the ordinary sediment in the water is sometimes sufficient to cause sticking.

3rd. The fish-traps necessarily used with most meters, while lessening the danger of the moving parts of the meter becoming blocked, are, themselves always liable to become clogged by pipe scales, leaves, and other similar stuff in the water. This is especially the case with meters on fire pipes, for the draft of water caused by a fire is likely to be so much larger than the normal draft, that it stirs up much sediment which remains quiet in the pipe with ordinary flows.

We have always advised that meters on fire services for those cases where meters absolutely can *not* be avoided, be placed in a by-pass with a gate in the straightway connection which is to be opened in case of a fire, but sealed shut at all other times. While we believe this to be the proper arrangement and worth its cost, it does not furnish a reliable remedy to the above troubles, for in a number of instances in our own experience, such by-passes have been absolutely forgotten in the excitement of a fire. Several of these cases, moreover, happened in plants where the care given to the fire service was excellent in every respect. Only recently one of our inspectors opened four 1-inch streams in a mill yard when the pres-

sure dropped from 70 to 33 pounds; the superintendent then *remembered* that there was a 4-inch meter on the 6-inch supply pipe. When the by-pass was opened the pressure rose to 51 pounds. Many of you will also recall the several examples of similar experiences given by Mr. Freeman in his remarks on this subject at the Hartford convention.

4th. Large meters with necessary gates and fittings, are very expensive and add a considerable percentage to the cost of a mill fire system. As often the amount of money available for such a system is limited, this results in a cutting down of the useful apparatus purchased and a replacing of it by something which actually lessens the efficiency of that which remains.

METERS TESTED AND TIME AND LOCATION OF TESTS.

In addition to the meters designed especially for fire pipes, and therefore designed to give large flows with small losses, a number of other types of meters were tested in order to get fairly complete data on the principal types of meters used, with the idea of getting comparisons and ascertaining what *not* to use on a fire pipe.

The following meters were tested :—

Meters Designed for Large Flows with Small Loss of Pressures:

METERS ADAPTED FOR FIRE SERVICE

Tested at Salem, July, 1896:

4-inch "Gem" meter, manufactured by National Meter Co.
6- " " " " " " " "
4- " "Torrent" meter, manufactured by Hersey Mfg. Co.
8- " " " " " " " "

Tested at Philadelphia, August, 1897:

6-inch By-pass with 2-inch "Crown" meter in the straight pipe.
4- " " " 1½- " " " " " " "
6- " Pratt & Cady check valve with 2-inch "Crown" meter around the check.

The last three meters were made up from ordinary pipe fittings by the Bureau of Water, Philadelphia.

METERS DESIGNED FOR VERY ACCURATE REGISTRY OF FLOWS, LARGE AND SMALL, BUT NOT FOR SMALL LOSSES OF PRESSURE:

NOT WELL ADAPTED FOR FIRE SERVICE.

Tested at Salem July, 1896:

4-inch "Crown" meter, manufactured by National Meter Co.
4- " "Hersey" " " " Hersey Mfg. Co.
4- " "Lambert" " " " Thomson Meter Co.

Tested at Lowell, September, 1897:

4-inch "Union" meter, manufactured by Union Meter Co.

Tested at Salem, July, 1896.

3-inch "Worthington" meter, manufactured by Henry R. Worthington.

The Worthington meter was obtained from the meter department of the City of Boston, through the kindness of Mr. John R. Murphy, water commissioner, the other meters were freely loaned by the manufacturers.

For the Salem tests, we are indebted to the Naumkeag Steam Cotton Co., for the free use of their yard, piping and general facilities, and to the Salem Water Board, who, through their superintendent, kindly granted us the use of the city water. The Lowell tests were made in the yard of the Lawrence Mfg. Co., where every facility was given us. Water from the reservoir of the Proprietors of the Locks and Canals was generously granted by their agent.

The Philadelphia tests were made through the kindness of Mr. John C. Trautwine, Jr., chief of the bureau of water, Philadelphia, and Mr. A. J. Fuller, assistant engineer, who freely granted us full use of their testing apparatus and also gave us the benefit of their tests and investigations on proportional or by-pass meters.

In carrying on these tests the larger part of the observations and computations were made by Messrs. F. M. Herrmann, A. L. Kendall and H. O. Lacount of the Inspection Department of the Factory Mutuals.

METHODS OF TESTING.

Plates I and II show the general arrangements of meters, gages, etc., for testing.

Plate I.

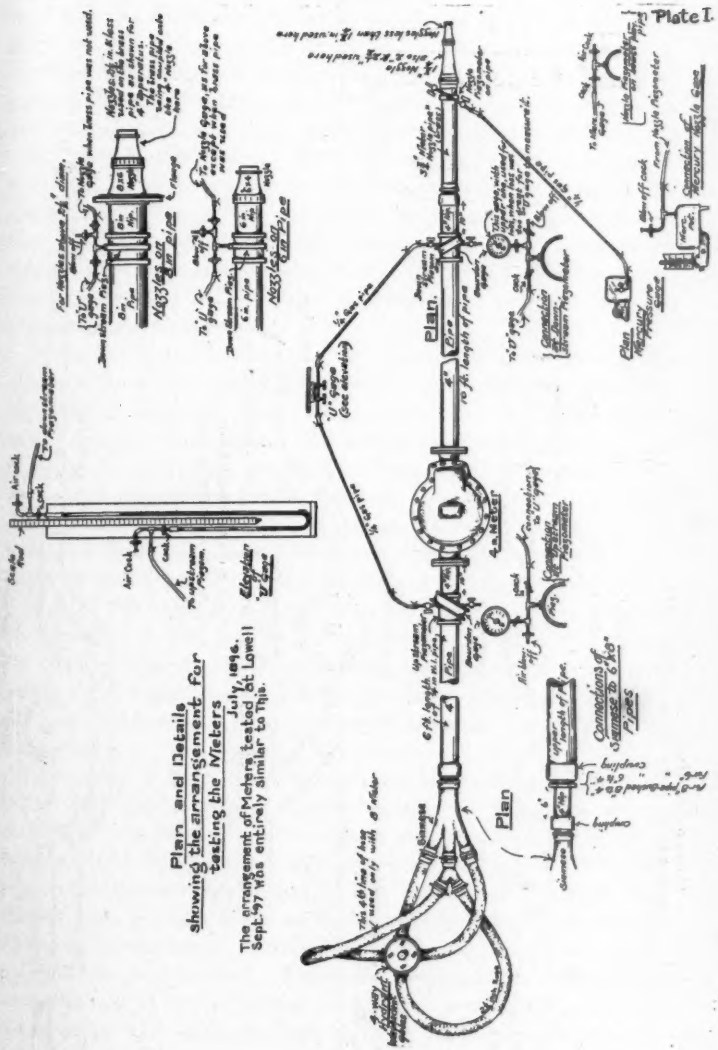
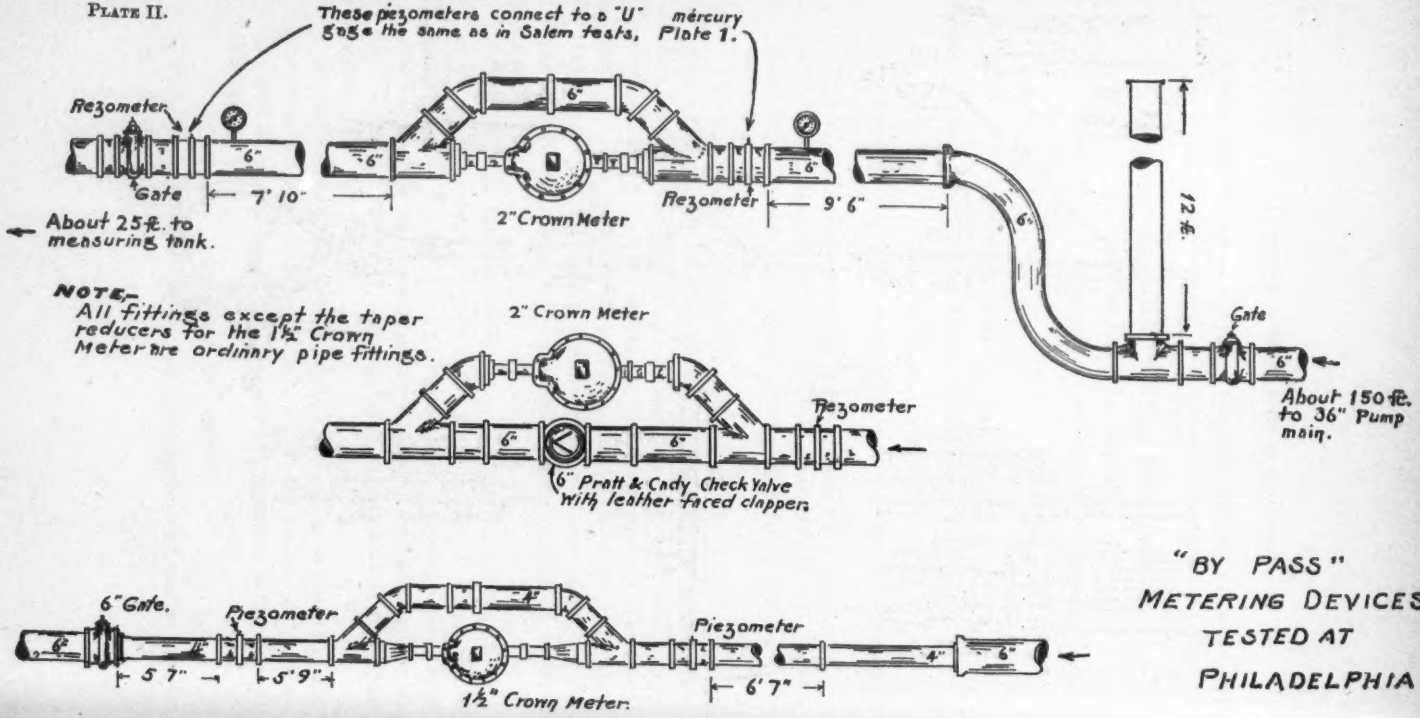

Plan and Details
showing the arrangement for
testing the Meters
July 1896.
The arrangement of Meters tested at Lowell
Sept. 97 was entirely similar to this.
Plan.
Plan

PLATE II.



"BY PASS" METERING DEVICES TESTED AT PHILADELPHIA

Just up stream from the meters was placed a piezometer with from seven to ten feet of straight pipe back of it, so that the water might enter it without whirls and eddies. Down stream from the meter a similar length of straight pipe was placed for the same purpose, to the end of which was screwed the second piezometer. A quarter-inch pipe was then carried from each piezometer to the "U" tube Mercury gage. With this arrangement the readings of the "U" gage gave directly the loss of pressure between the piezometers. The actual loss caused by the meter was that read from the "U" gage less a slight correction for the friction in the straight pipe between the piezometers. In the few cases where the loss exceeded the range of the Mercury gage, ordinary Bourdon pressure gages were used.

In the Salem and Lowell tests, the quantity of water flowing was measured by meter nozzles, according to the methods developed by Mr. John R. Freeman, (See Trans. Am. Soc. C. E., 1890) as well as by the meter under test. The nozzles used were of the smooth type and varied in diameter of outlet from ½-inch to 5 inches. For very small quantities, ⅛, ¼ and ⅜ inch holes in thin brass plates were used. In the Philadelphia tests the quantity flowing was measured in a large tank with a swinging spout attachment, the depth of which was accurately determined by a hook gage.

Most of the nozzles used had been very accurately calibrated by Mr. Freeman in his experiments at Lawrence and Nashua, so that the quantities by the nozzle may be considered as certainly accurate within about 1 per cent, and probably correct within one-half of 1 per cent. About the same degree of accuracy was obtained at Philadelphia.

In making a test, water was allowed to run for a few minutes before observations were commenced to allow all to come to normal conditions. In most of the Salem tests at a given signal the meter was read and half-minute readings commenced on the "U" gage and on the Mercury nozzle gage. The meter was also read each minute, thus giving a record of the uniformity of flow. At the end of a definite number of minutes, the meter was again read, on signal, and the test stopped. From the average of the nozzle pressures the rate of flow in gallons per minute was computed, and from the average "U" gage readings the loss of pressure corresponding to this flow determined.

In the later tests the exact time in which the meter registered an even number of cubic feet, was noted with a stop-watch, the nozzle measurements being made the same as before. This latter method is the better one as it is free from errors caused by inaccuracies in the graduations of the meter registers, and as it is easier to operate a stop-watch when a dial hand reaches a certain point than to catch the exact reading of a moving meter on signal. With the first method however, the quantities run were generally so large that any errors from these causes would be very small in percentage. When the tank was used instead of the meter nozzles, the rate of flow was found by dividing the total gallons caught in the tank by the time of the test, all other observations being the same as before.

With the ordinary meters the chief point sought was the loss of pressure with various flows, with the meters in various conditions, though the data obtained gave considerable interesting information as to the accuracy with which the meters registered. With the proportional meters the friction loss was also obtained, but in addition the co-efficient by which the reading of the small meter must be multiplied to give the total quantity was carefully determined. In the tests with the tank, the total cubic feet caught in the tank divided by the cubic feet registered by the small meter gives the co-efficient.

RESULT OF TESTS—FRICTION LOSS.

The main results are given in Table I, and are plotted in Plates III and IV. Tables II and III simply give the data of Table I in another form.

From Table I, we find, for example, taking a flow of 500 gallons per minute, or two good, stiff $1\frac{1}{8}$-inch fire streams, which is more than a 4-inch pipe would be called on to supply ordinarily the following losses of pressure due to the meter:

In a	4-inch	"Hersey" Meter	40	pounds.
"	4-inch	"Crown" "	31	"
"	4-inch	"Lambert" "	13	"
"	4-inch	"Torrent" "	8	"
"	4-inch	"Union" "	6.4	"
"	4-inch	"Gem" "	4	"
"	6-inch	"Gem" "	1.1	"
"	8-inch	"Torrent" "	0.7	"

TABLE I.

Loss of Pressure Caused by Meters.

Gallons per Minute Flowing Through Meter.	Equiv. No. of 250 Gallons Fire Stream.	Loss of Pressure in Pounds due to the Meter.											
		Current Meter.		Disc M't'r	Rotary Piston.			Current.		Proportional.			Piston.
		4 in. Gem.	4 in. Torrent.	4 in. Lambert.	4 in. Crown.	4 in. Hersey.	4 in. Union.	6 in. Gem.	8 in. Torrent.	6 in. By Pass 2 in. Crown.	6 in. Check 2 in. Crown.	4 in. By Pass 1½ in. Crown	Worthington.
50		.....	...	....	0.3	0.5	...	....	....	....	0.1	0.1	1.6
100		.....	..	0.2	0.6	1.4	1.6	0.2	...	....	....	0.1	0.2	6.0
200		. ....	0.8	1.3	2.2	4.9	6.1	1.1	.. .	..	.. .	0.2	0.5	23.0
	250	1	1.1	2.0	3.4	7.5	9.3	1.7	....	....	0.1	0.3	0.8	34.8
300		.....	1.6	2.9	4.8	10.9	13.3	2.5	0.4	0.3	0.1	0.4	1.1	48.0
400		.... .	2.7	5.1	8.2	19.9	25.1	4.2	0.8	0.5	0.2	0.6	1.9	....
	500	2	4.1	8.1	12.9	31.2	40.0	6.4	1.1	0.7	0.3	0.8	2.9	....
600		.....	6.1	11.9	18.7	...	....	9.4	1.7	1.0	0.5	1.1	4.4	....
700		.....	8.3	16.4	25.1	...	....	12.8	2.3	1.3	0.7	1.5	6.1	....
	750	... 3	9.5	18.9	28.6	....	....	14.6	2.6	1.6	0.7	1.7	7.2	....
800		.....	10.8	21.4	....	..	....	16.6	3.0	1.8	0.9	2.0	8.3	....
900		.....	13.5	...	...	...		20.8	3.9	2.3	1.2	2.5	10.9	...
	1000	4	....	..	...	....	...	25.5	4.8	2.8	1.4	3.0	13.9	....
	1250	5	...	...	....	..	....	..	7.2	4.5	2.3	4.8	...	....
	1500	6	...	...	....	..	....	....	10.0	6.4	3.1	7.1	....	....
1600		.....	...	...	...	...	....	....	...	7.3	3.5	8.6	...	....
	2000	8	...	...	....	...	....	....	....	...	5.6	..	....	...
	2500	10	....	....	...	...	....	....	....	...	....	....	..	...

The Gem, Crown and Hersey meters had fish traps as a part to the meter, so that the losses above includes the trap. The Torrent, Lambert, Union and Worthington meters use a separate trap; they were however tested without traps.

TABLE II.

EQUIVALENT PIPE LOSSES. (Meters in Normal Condition.)

	4 in. Gem.	4 in. Torrent.	4 in. Lambert.	4 in. Crown.	4 in. Hersey.	4 in. Union.	6 in. Gem.	8 in. Torrent.	6 in By Pass 2 in. Crown.	6 in. Check 2 in. Crown.	4 in. By Pass 1½ in. Crown.	3 in. Worthington.
Approximate feet of new, straight, clean, cast iron pipe that would cause the same loss of pressure as the meter.	45	80	130	310	385	67	180	425	58	122	32	625

The Worthington Meter was an old one and therefore not fairly comparable with the new clean meters.

TABLE III.

LOSSES CAUSED BY METERS AT DIFFERENT VELOCITIES.

Velocity Feet per Second in Pipe Size of Meter.	Pounds Loss in Pressure Caused by Meters.											
	4 in. Gem.	4 in. Torrent.	4 in. Lambert.	4 in. Crown.	4 in. Hersey.	4 in. Union.	6 in. Gem.	8 in. Torrent.	6 in. By Pass 2 in. Crown.	6 in. Check 2 in. Crown.	4 in. By Pass 1½ in. Crown.	3 in. Worthington.
5	0.70	1.2	2.1	4.8	6.0	1.0	0.90	1.75	0.3	0.6	0.5	7.5
7½	1.55	2.8	4.7	10.7	13.3	2.4	2.15	3.92	0.6	1.4	1.0	16.5
10	2.60	4.9	8.0	19.4	25.0	4.0	5.00	7.00	1.1	2.4	1.8	28.0
12½	4.00	7.8	12.8	31.1	39.8	6.2	5.70	.....	1.8	3.6	2.7	41.4
15	5.80	11.8	18.5	.....	.....	9.2	8.00	....	2.5	5.4	4.2	.....
20	10.20	20.4	.....	...	.....	16.0	.....	...	4.4	...	8.0	.....

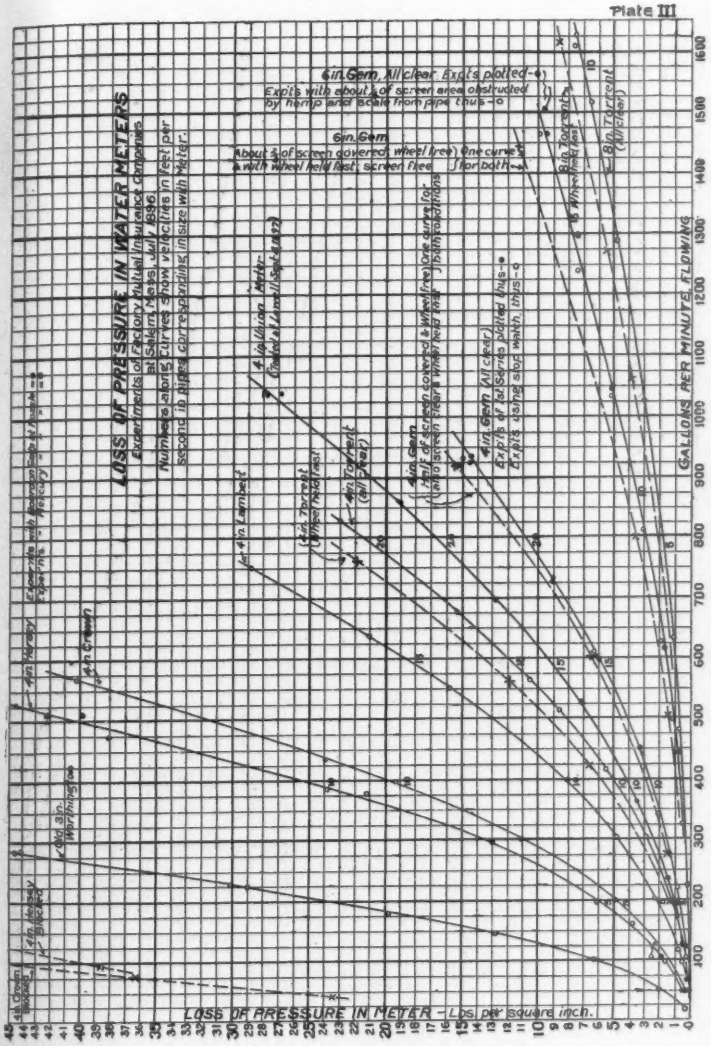
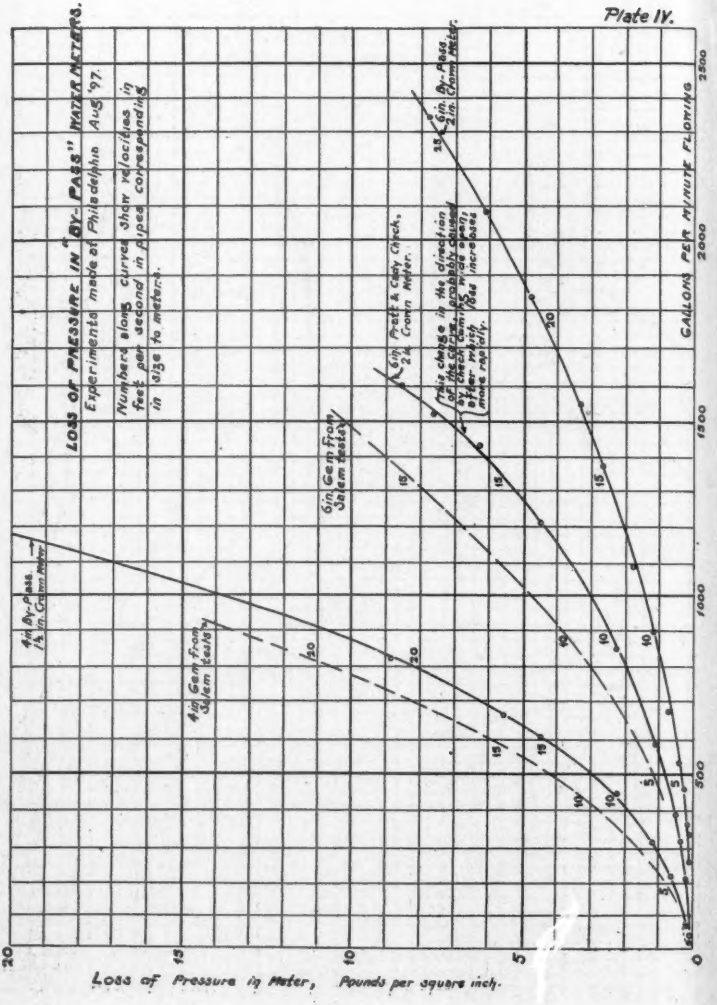


Plate III
LOSS OF PRESSURE IN WATER METERS
Experiments of Factory Mutual Insurance Companies
at Salem, Mass., July 1896
Numbers above curves show velocities in feet per
second in pipes corresponding in size with meter.
6 in. Gem. All clear. Expt's plotted -o-
Expt's with about ½ of screen area obstructed
by hemp and scale from pipe, thus -o-
6 in. Gem.
About ½ of screen covered, wheel free. One curve
with wheel held fast, screen free. } for both
4 in. Gem (All clear)
Expts of 3 Series plotted thus -•
Expts. with slot teeth, thus -o-
4 in. Gem
(half of screen covered & wheel free) One curve for
this screen & one wheel held fast } for both
4 in. Lambert
4 in. Thomson
(Gallup Meter)
(Factory Mut. Ins. Co's Expts. Sept. 1892)
4 in. Tolman
(Wheel held fast)
4 in. Tolman
(All free)
4 in. Crown
4 in. Hersey
Expts. with Hersey
Meter
6 in. Hersey
Expts. with Hersey
Meter
6 in. Worthington
8 in. Tolman
(All free)
8 in. Tolman
(Wheel held fast)
GALLONS PER MINUTE FLOWING
LOSS OF PRESSURE IN METER - Lbs. per square inch.

Plate IV.


LOSS OF PRESSURE IN "BY-PASS" WATER METERS.
Experiments made at Philadelphia Aug '97.
Numbers along curves show velocities feet per second in pipes corresponding in size to meters.
4in By-Pass. 1½ in. Crown Meter.
4in Gem from Salem tests.
6in Gem from Salem tests.
6in Pratt & Cady Check. 2in Crown Meter.
This change in the direction of the curve probably caused by the commencement of the by-pass flow increasing more rapidly.
8in By-Pass 2in. Crown Meter.
GALLONS PER MINUTE FLOWING
Loss of Pressure in Meter, Pounds per square inch.

Again, taking 1000 gallons per minute or four good $1\frac{1}{8}$-inch streams, we have the losses as follows:

In a	4-inch "Union"	Meter	25.5 pounds.
"	4-inch "Gem"	"	16 "
"	6-inch "	"	4.8 "
"	8-inch "Torrent"	"	2.8 "

It is to be kept in mind that a 4-inch meter would in practice seldom or never be called on to deliver so much, 1,000 gallons per minute. But these figures are instructive in showing the great difference in friction loss in meters of different types.

In a subsequent test of a number of the meters the moving parts were securely wedged in place so that they could not move, thus representing the conditions when a stick or stone gets into a meter. The results were as below:

In the	4-inch	"Gem"	Meter,	blocking increased the friction	about	10	per cent.
"	4-inch	"Torrent"	"	"	"	15	"
"	6-inch	"Gem"	"	"	"	20	"
"	8-inch	"Torrent"	"	"	"	20	"

The "Crown," "Hersey," "Union," "Lambert" and "Worthington" meters can be blocked in such a position that but little water can pass through them, so that under these conditions they would practically *destroy* a fire service.

These results clearly show up the obstruction caused by meters. It is to be remembered that these figures were obtained with new meters, and everything free and clean; that time would increase the loss of pressure caused by a meter there can be no question. While the losses in the "Gem" and "Torrent" meters are not excessive, it is well to remember that many of the city and town water supplies are at a pressure which can be considered as only moderate for fire streams, therefore, the desirability of avoiding every pound of unnecessary loss in getting the water from the city or town mains to the nozzle of the fire stream, and it is also to be remembered that their apertures are liable to be suddenly obstructed by the gravel stone, stick, eel scale or other foreign material stirred up and brought along with the rush of water caused by the fire draft.

FISH-TRAPS.

In the Salem tests the water used was taken from a 4-way hydrant at the end of several hundred feet of 10-inch yard pipe which had been recently laid—this 10-inch pipe connected with the city mains.

After the first heavy draft of water through this pipe, which occurred with the 6-inch "Gem" meter, when about 1,500 gallons per minute were drawn, *it was found that in this brief period about three-quarters of the surface of the screen in the fish-trap was covered with hemp, pipe-scale and mud*, closing about from one-fourth to one-third of the area.

To get an idea of the effect of partial blocking of the fish-trap, one-half of the screen in the trap of the 4-inch "Gem" meter was covered by a board, in which condition it was found that the loss through the meter was increased about 10 per cent., or about the same as if the trap was free and the wheel blocked. In the 6-inch "Gem" meter, two-thirds of the screen was blocked by a board and the loss thereby increased about 20 per cent., which happens again to be about the same as for the blocking of the wheel.

The area of the screen in the trap for the 4-inch "Gem" meter was about 2.8 times the area of a 4-inch pipe.

The screen for the 6-inch "Gem" trap was about 3.2 times the area of a 6-inch pipe.

The short time which it took when first testing the 6-inch "Gem" meter to obstruct one-third of the screen area, would indicate that in case of the long draft of a severe fire a very serious blocking would be entirely possible; this, however, of course depending much on the care in laying the pipe to keep all obstructions out of it and the frequency with which the mains were thoroughly blown off.

Our experience with screens on the suctions of fire pumps gives further emphasis to this point. While with the ordinary drafts of water—such as when the fire pump is occasionally used at slow speed for boiler feeding or similar work during the time the regular pumps are being repaired—no trouble whatever may be noticed, though the strainer is half covered by grass, gravel or scale; but let the extreme quantity needed for fire fighting be called for and there is dangerous inability to get a full supply.

The fact that obstructions in pipes may remain unnoticed with ordinary drafts and are likely not to be discovered till the heavy draft of a fire calls attention to them, is further illustrated by a

fire which occured some time ago in one of New England's large manufacturing plants, where, after the fire, an important gate was found to be open only about two inches. Again, when the Union Station in Providence burned a year or so ago it was found when, *after* the fire, the cause for weak streams was being looked into, that a main 16-inch gate was shut, the water or at least a part of it, having to reach the fire through a circuitous 6-inch pipe.

With such meters as the "Gem" or "Torrent" where the blocking of the moving parts is not serious, it would be better as far as a fire service is concerned to omit the fish-traps entirely; this is, however, objectionable as without traps there would be danger of drawing a stone or stick into the revolving parts and breaking them every time a large quantity of water was drawn. This, in fact, happened in Salem when testing the 8-inch "Torrent" meter, as no fish-trap was used with it,—a small stone lodging between the guides and the revolving turbine, breaking several buckets. With the proportional type of meter the fish-trap would of course be on the small meter and entirely unobjectionable.

With the above facts in mind, can it be wondered that those who are responsible for the protection from fire of properties whose values often run into the millions, look with serious apprehension at the installation of meters on the fire service pipes.

Drawing from Mr. Freeman's remarks at Hartford, already referred to herein, we do not believe that, except in rare cases, the men who manage the large factory industries of the country would purposely steal water for the sake of saving its cost. That employees may ignorantly or for their convenience, draw water from hydrants, sprinkler blow-offs, or similar outlets on fire systems, is a possibility. In most mill fire systems the piping is laid out in such a simple and direct manner that it is easy for the water works inspector to make himself reasonably sure that no water is being improperly used. If surreptitious use or hidden connection is feared a short ¾-inch by-pass may be tapped in around the main gate into the yard, and a ¾-inch meter kept set in this by-pass. Then occasionally without warning let the water works inspector shut the main gate for ten minutes and see if the meter moves. This will detect any hidden connection. Moreover, it is entirely feasible to seal the hydrants and blow-off gates on the sprinkler systems, using a lead seal similar to that universally employed on

freight-cars. Such a seal can be easily broken in case of fire, but will prevent any draft of water through the ordinary channels without giving clear evidence of the fact.

Such arrangements as the above necessitate absolutely separating fire supply pipes from those bringing water for manufacturing purposes. In general, however, a pipe much smaller than the fire pipe which may be equipped with any meter the water department desires will furnish all the water used for manufacturing and can be put in at a cost that is entirely reasonable. This is certainly better for the water departments than to use a large meter on the fire main, as a smaller meter allows a closer registering of the quantity used.

ABILITY OF LARGE METERS TO DETECT SMALL FLOWS.

In those few cases where the interest of the water department seems imperatively to require a meter on the fire service pipes, we have heretofore advised the "current" type of meter, such as the "Gem" or "Torrent," and occasionaly find that the superintendents of water departments feel that they are not safe even with these meters from the fear that their large capacity renders it possible to draw considerable quantities through them without registering. To see how serious this matter was we carefully experimented with the large capacity meters to see just where their limit of sensitiveness came. The following results were obtained:

The 4-inch "Gem" meter with 8½ gallons per minute flowing did not register. The wheel was then started by opening some extra cocks thus allowing a larger flow, but when the cocks were closed it stopped again. With 19 gallons per minute flowing the meter registered at the rate of a trifle over 17 gallons per minute. The 4-inch "Torrent" meter with 11 gallons per minute flowing registered at the rate of about 10 gallons per minute. The 6-inch "Gem" meter with 11 gallons per minute flowing, did not register and the wheel did not continue to move at this quantity even after being started by increasing the flow. With 13 gallons per minute flowing, the meter registered at the rate of 4 gallons per minute and with 22 gallons flowing, at the rate of about 19 gallons per minute.

The 8-inch "Torrent" meter with 8½ gallons per minute flowing, registered at the rate of 2 gallons per minute. With 20 gallons per minute flowing, at the rate of about 18 gallons per minute. These

tests were made with the small orifices in thin brass plates, pressures at the orifices being in the neighborhood of 60 pounds.

These results show that the amount of water drawn, where the pressure is good and the service pipes are of liberal size, by an ordinary $\frac{5}{8}$-inch sink tap, or by an ordinary garden hose with $\frac{3}{8}$-inch nozzle, would be registered with tolerable accuracy by a new 6-inch "Gem" or new 8-inch "Torrent" meter, but that about half of this rate of flow could be drawn without registering. A discharge of a single automatic sprinkler would be well registered.

The piston and disc meters can detect and measure considerably smaller flows. The 4-inch "Union" meter was the only one which was specially experimented with as to sensitiveness. With this meter the flow through a $\frac{1}{8}$-inch sharp edged hole in a thin brass plate under 90 pounds pressure, or about 2.8 gallons per minute was the lowest which would move the meter. The meter recorded about one-half of this flow, the other half being leak. With a $\frac{3}{8}$-inch orifice, under 5.4 pounds pressure, giving 5.7 gallons per minute, the meter was about 16 per cent behind in quantity. With the same orifice as 15 pounds, giving 9.6 gallons per minute, the meter was about 5 per cent slow.

With the 4-inch "Lambert," "Crown" and "Hersey" meters, $8\frac{1}{2}$, $14\frac{6}{10}$ and $21\frac{5}{10}$ gallons per minute, respectively, were the smallest quantities drawn, the meters registering these flows satisfactorily.

We made no tests on the "Venturi" meter, as this has been very fully reported upon by others. The loss caused by this meter is so small as to be practically unobjectionable. The meter may, however, introduce an obstruction if the brass lining of the throat is not made long enough, from tubercles forming on the unprotected iron near the throat and choking the passage. This trouble can of course be easily remedied by extending the lining on both sides of the throat for a liberal distance. Large "Venturi" meters, it is understood, cannot satisfactorily measure very small flows.

In the Philadelphia tests the by-pass arrangements experimented on, were those which the Philadelphia Department had found after a good many experiments, gave the best results. Their data being freely open to us, made it possible to quickly come to conclusions as to these devices, thus saving us a large amount of experimenting. The results were as follows: With the 6-inch by-pass and 2-inch

"Crown" meter it was found impossible to keep the meter moving with a total flow less than about 250 gallons per minute. With a 4-inch by-pass and 1½-inch "Crown" meter, about 45 gallons per minute was the lowest quantity we succeeded in registering. These results cannot be considered satisfactory.

Table IV and Plate V give the co-efficients by which the readings of the small meter must be multiplied to give the total quantities, and show that with larger quantities these devices can measure with tolerable accuracy. If with the 6-inch by-pass the co-efficient be taken as 29 the greatest deviation from the co-efficient, found experimentally, would be about two, over a range from 500 to nearly 2500 gallons per minute. This would mean at the worst point an error of about 6½ per cent in the quantity measured.

With the 4-inch by-pass with from 200 to 1800 gallons per minute flowing, the average co-efficient would be about 16, the maximum found in the experiments being a trifle over 17, and the minimum a trifle over 16. The maximum error being about 6½ per cent as before.

As the whole idea of the proportional meter is to create a loss of pressure between the points of connections of the small meter, it was thought that possibly the check valve, ordinarily necessary in a factory fire service to keep the fire pump water off of the public mains, might be used instead of a by-pass to cause this necessary loss of pressure, thus making unnecessary any additional obstruction. The use of a check valve for this purpose was also suggested by Mr. Crandall in his paper before this association, read February 10th, 1897.

With a 6-inch Pratt & Cady check valve, with leather faced clapper and a 2-inch "Crown" meter in a by-pass around the check, we found about 45 gallons per minute, the lowest flow which would keep the small meter running. With this flow the co-efficient was about four. It rose rapidly to about 23 at 300 gallons per minute, the average being then about 22 from 300 to 2500 gallons per minute. The maximum co-efficient found was 23½, the minimum 20½, giving curiously about 6½ per cent as the maximum error as with plain by-passes. While these results are not especially satisfactory, it would seem that the idea has very hopeful prospects of development.

TABLE IV.

Co-efficients for By-Pass Meters.

Rate of total flow in Gallons per minute.	Co-efficients by which readings of small meters must be multiplied to give total quantities passing.		
	6 in. By Pass. 2 in. Crown.	6 in. Check. 2 in. Crown.	4 in. By Pass. 1½ in. Crown.
10	....	...	..
15	....	....	....
20	....	....	....
30	....	....	....
40	....	4.0	34.5
50	....	6.0	28.0
75	....	6.0	22.5
100	....	8.0	20.8
150	....	12.2	16.5
200	....	16.8	15.5
250	38.0	20.0	15.5
300	35 0	22.7	15.7
400	31.3	23.1	16.4
500	30.8	22 9	16·5
600	30.6	22.9	16 1
700	30 0	22.0	16 1
800	29.0	21 1	16 5
1000	28.0	21.0	16.6
1200	28.2	21 3	16.7
1400	28.8	21.6	16.8
1600	29.3	21.1	17.0
1800	29.5	21.2	17.1
2000	29.3	21.4	....
2200	29 3	21.6	...
2400	29.5	21.8	....
2600	....	22.1	....

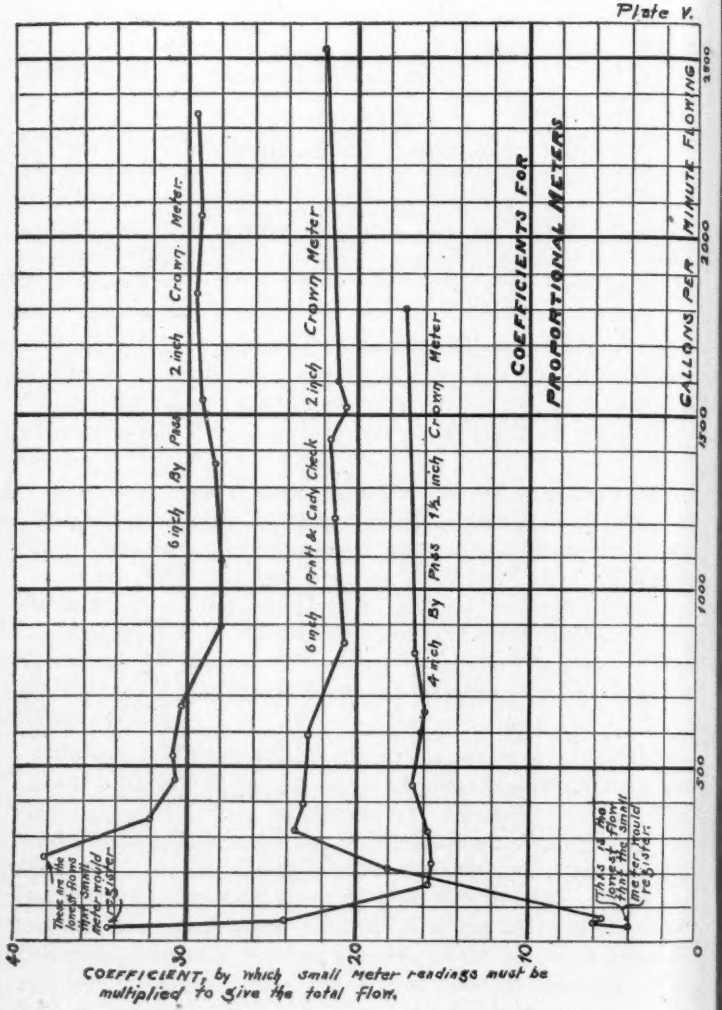


Plate V.
COEFFICIENTS FOR PROPORTIONAL METERS
GALLONS PER MINUTE FLOWING
3500
2000
1500
1000
500
0
40
30
20
10
0
6 inch By Pass 2 inch Crown Meter
6 inch Pratt & Cady Check 2 inch Crown Meter
4 inch By Pass 1½ inch Crown Meter
These are the lowest flows that small meter would register
This is the lowest flow that the small meter would register
COEFFICIENT by which small meter readings must be multiplied to give the total flow.

If in some way *which could not possibly endanger the full opening of a check valve* a slight *initial stick* can be given to the clapper, *all* the water at small flows would be forced through the small meter, thus bringing the sensitiveness of the whole device down to that of a 1 or 2-inch meter of the best type. With large flows, the check would open, and a quantity would be measured on the proportional plan. Mr. Freeman some years ago proposed a check valve with a weighted clapper for this purpose, but has not found time to work out the idea in practical shape to his satisfaction, but it appears entirely practicable.

In Mr. Crandall's paper it is suggested that the spindle of the clapper be carried through the valve casing, and an outside weighted lever attached, with the weight so arranged that it will be thrown off when the valve opens. The possibility of dangerous sticking of the spindle, or of the external lever becoming carelessly blocked by some obstruction in the valve pit, would make this arrangement a little open to suspicion. It would seem, however, that these dangers could be gotten over and a satisfactory solution of the problem found after due study, and we shall be much pleased if some member of this society will work out the details of such a device.

In most fire systems it is illegal to draw *any* water except for fire, when the quantity used is not cared for, without notifying the water department. It would, therefore, seem that the check valve arrangement would put about as useful information into a superintendent's hands as if he could swear to the exact quantity used, i. e., if he was sure of the *fact* of sinning, the *degree* of it would be of minor importance.

This device, besides its action as a *detector*, would, however, give some idea of the degree, though it has one curious quality in which it resembles the general idea of the working of our common law in that it jumps hardest on the man who does not steal enough. If, for instance, only a small quantity is taken, i. e., not enough to overcome the initial stick of the clapper, and then the water department figures the bill, using the average co-efficient of 20 or 30, the mill will certainly pay a fine rather than a water bill, while if a large quantity was stolen, the fine element would disappear.

This might lead to disputes, but as the law had been broken anyway, the offending one would have little ground to stand on. The weighted lever arrangement, moreover, with the falling off weight

mentioned by Mr. Crandall, suggests the possibility of some sort of a recording device which would show if the clapper moved from its seat.

Such an arrangement would seem to give us a device absolutely unobjectionable to insurance companies, but one which would appear to give complete protection to water departments.

The use of the meter nozzle gave a means of learning the average accuracy of the various meters tested. In general, it was found that meters of the current type, with flows slightly above the minimum mentioned, measured the water within from three to four per cent of the truth, and often closer, though occasionally a somewhat larger deviation would be found. With the disc and piston meters tested the average accuracy was from one to two per cent. These results would seem to be good enough when measuring a liquid no better than water.

CONCLUSION.

In conclusion, our position on meters, with the devices *now* obtainable in the market is this :

1st. We should earnestly advise that *every other means* for safe guarding the interests of the water department be exhausted before resorting to meters.

2d. Where meters are unavoidable, we should urge the use of the current type, such as the "Gem" or "Torrent."

(a) Because the loss of pressure caused by these meters is moderate.

(b) Because if their moving parts become stuck the friction loss is not seriously increased.

3d. We do not consider the ordinary types of disc or piston meters at all suitable for fire pipes from the fact that they can almost completely stop the flow, if their moving parts become blocked.

4th. In cases where meters must be used, we should advise that they be placed on a by-pass, with a gate in the straitway connection. This straitway gate should be provided with an indicator post, and if possible, the meter should be so placed that this post will be in a conspicuous location. It is also a good plan to put gates in the by-pass, on each side of the meter, so that it may be examined or repaired without shutting off the fire service.

DISCUSSION.

THE PRESIDENT. The paper is now open for discussion. Is there any one who noticed anything in the paper with which he did not quite agree, or is there some meter man who can tell us how to remove the obstruction, or possibility of obstruction, that exists in connection with his particular type of meter? It seems as though there must be something to be said in the discussion of this paper, which will be of interest to us all.

MR. FRENCH. Mr. President, I should like to learn the general opinion of the superintendents as to how much value this sort of detector idea would have. That is, if you had an arrangement which would simply give you the information that *some* water had been drawn, wouldn't that, in a great many cases, be all you would care to know? This is a problem on which we find you have a good deal more to say when we come to meet you individually, and want certain things done, than you seem to be willing to say this afternoon, but we would like to get what ideas we can from you now, for it may help us later on. We imagine that with the attempts that now seem to be made everywhere to reduce waste, perhaps the fire service pipe would be jumped upon about as soon as anything, although, as I have said, our experience would indicate that they are not a very great cause of waste. We want to get at just what is really necessary for the protection of that sort of a service. You see our idea of the subject, anyway.

MR. FISH. Is it a fact that fire service pipes in New England are generally metered?

MR. FRENCH. We have very few meters on fire pipes, and have always taken the ground strongly that they should not be there; but we do find every now and then a desire, and perhaps it is increasing, to put meters on, and occasionally we find a place where it is impossible for us to convince the superintendent that a meter should not be put on. A very small percentage of our factory sprinkler and yard hydrant fire services are metered, probably not one in twenty, but still there are enough to make it somewhat of an important question with us.

MR. FISH. It is novel to me that they have meters for fire services.

MR. FRENCH. Perhaps I should explain that, the properties which the Factory Mutuals are principally interested in are similar to the large mills at New Bedford, Fall River, Lowell and Lawrence, where they have a large mill yard, and very often an 8, 10 or 12-inch connection, from the city service right into the yard, and a complete system of fire hydrants and automatic sprinklers, independent of the supply for manufacturing purposes. Check valves are placed in these connections so that the mill fire pumps cannot pump back into the public mains. It is the general custom for the mills to allow the water works inspector to enter the yard at any time, and to see just exactly what is going on. In some cases, where there seemed to be cause for suspicion, the water department has sealed all the blow-off gates, each hydrant, and the valves controlling the sprinklers. It is understood, of course, in these cases that the fire system is entirely separate from the supply for mill use, so that excepting in case of fire there is no occasion for any draft from it whatever.

THE PRESIDENT. Is there any superintendent here who has meters on fire service pipes, who would like to say something on this subject? I don't like to call upon anybody by name, but I will ask Mr. Walker if he has ever had any experience in that direction. (Applause.)

MR. WALKER. As far as fire pipes are concerned, I confess that sometimes one feels as if he would like to have them metered. For instance, you have a mill where there are pipes for fire purposes only, they will take the city water to fill their boilers with occasionally, and use it generally as they see fit. We had one case in Manchester where, unfortunately, their reservoir was lower than ours, and on one occasion when something ailed their pumps, they opened the gate and filled up their reservoir from ours. There wasn't any meter in use there. Where the supply comes right from the city, I am satisfied that there ought to be something done to meter those places. The insurance men want a 12-inch pipe for a 50-foot mill. (Laughter.) They want to cover it all over with sprinklers; naturally, they don't want any loss. They are very anxious, and they have a great deal of information on these subjects, and they tell us just how big a pipe is needed for this and that, wherever they have any insurance on property. (Laughter.)

A gentleman came to me last year and said he was going to try the hydrants in his yard and wished me to come down or send a man. He was a pretty good sort of a fellow, and he wouldn't open them without my permission. He said, "I have made up my mind I am not going to put anything new in, and if the insurance company won't insure the mill as it is now, it needn't insure it at all, and I will do it myself." These insurance men come around and look at your plant and tell you what you ought to have done, so really the superintendent hasn't much to say about it. They generally take all the measurements, and tell the superintendent what kind of pipe they want in such a street, where a new depot is going up, or a new mill, or something of that kind. I am not prepared to talk on this subject, but I should really like to talk on it about half a day (laughter), because I have been afflicted somewhat by these insurance fellows. I guess, however, I won't air my grievances this afternoon, because I haven't got in very good shape what I would like to say. But I am satisfied of this much, that some kind of a meter—I shan't recommend any particular kind, for they all go back on me at times, as I have said before—but I am satisfied that there should be some kind of a meter on all fire services so that the mills can't steal the water. The bigger the company the more it will steal. (Laughter.)

THE PRESIDENT. I would like to ask Mr. French if he does not consider that there is a large loss of water on account of fire sprinklers, which cannot be attributed at all to fires? For instance, in a factory in Lynn I have understood that on an average nine sprinklers burst in a week; and whenever a head bursts it necessitates the running of the full amount of water contained in the pipes at times. And it does seem to me that there must be a large use of water on account of these fire sprinklers that we don't know anything about. It goes into the general consumption, the 40 or 50 per cent of water we pump that doesn't do anybody any good. And while this does not really enter into the question of the use of meters on the fire service generally, if we had meters on the sprinkler service they would pay for the amount of water that they use when there is no fire, and which really is quite an important factor, in my opinion, in the water works supply. I would like to ask Mr. French if it is not a fact that there is a large amount of water wasted, owing to the irregular working and repair of these points?

MR. FRENCH. In answer to Mr. Haskell—I assume he means water wasted by the breaking open of an automatic sprinkler when there is no fire.

I am sure Mr. Haskell has been misinformed about the danger of heads opening when there is no fire, and that nine breaks in the whole city of Lynn for a year would be more likely the case. Moreover, of these breaks, many would be from accidental blows and therefore instantly discovered, and very few would open of their own accord. In the properties insured by the Mutual companies there are over two million (2,000,000) sprinkler heads, but our experience is that the loss from water damage is almost nothing. We do have sprinklers break open, but the loss caused is very, very small, and considering the immense number of sprinklers that we have, the breaks are very, very infrequent. I know in Lynn, because my home is there, there have been one or two, perhaps more unfortunate cases of sprinklers breaking in shoe factories, and the break not being discovered for some time. But in the Factory Mutual work every plant has a watchman, often more than one watchman, so that the bursting of a spinkler is generally discovered promptly. In fact, so low has been the loss from sprinklers that to allay the fears of some of the mill people, when asked to put sprinklers over valuable parts of their plants, two of the largest Mutual companies have taken up sprinkler insurance, that is, they insure against water damage from the accidental bursting open of sprinklers and fire protection pipes and have found the actual losses to be insignificant. It is probably within the truth to say that less than one sprinkler in fifty thousand of the better types breaks open accidentally in the course of a year. I am positive that the waste of water from the breaking of automatic sprinklers is of no importance whatever.

THE PRESIDENT. As I understand the value of an automatic sprinkler, it is simply to effect one purpose, and that is to stop a fire right at its inception. These sprinkler heads are distributed through the factory, and if the heat at any one point gets above a certain degree, the sprinkler operates. Immediately a certain amount of water escapes, but no greater amount of water passes through the pipe than can pass through one sprinkler, which, in the case of a 6-inch meter, would be an almost infinitesimal amount.

My object in making this explanation is this: I think all super-

intendents will agree with me that it certainly would be proper to pay the city for all the water used to keep these pipes in order. I do see force in the argument that we ought to supply these sprinklers with water for fire purposes, the same as we supply water to the hydrants for fire purposes. Where a city gives water for fire purposes to a hydrant free of charge, perhaps they might be expected to do so to fire sprinklers, from the fact that a small amount of water used by the fire sprinkler to extinguish a fire, would save a large amount which would have to be used later in case the fire broke away. But the principal objection I saw, or the two objections I saw, as the paper was read, which the sprinkler people make to the use of meters on their pipes, were: first, that they reduced the pressure of the water; secondly, that it might be possible for an obstruction to stop the flow of water entirely. Now it occurs to me that there is little water used by a fire sprinkler until its point of efficiency is passed. I consider that a fire sprinkler is a very good thing until the fire department gets there; the moment the fire department gets there it is worse than useless, it does not help the fire department a great deal in putting the fire out, and, consequently, there are only, perhaps, one or two, or three, or at the most, five minutes, when the fire sprinkler is expected to do any work. If that is the case, with the amount of water that can flow through these one, two, three, four or five points, it would not effect the efficiency of the sprinkler at all to have a 4-inch or a 6-inch meter on the supply. That is the way it looks to me, but I should like to get a little information from Mr. French in that direction.

MR. FRENCH. There is no doubt whatever that the introduction of automatic sprinklers lessens the total consumption of water for fire purposes if you have a small brief fire to fight instead of a large fire lasting for hours. The amount of water drawn by the ordinary automatic sprinkler at 60 pounds pressure is in the neighborhood of 45 gallons a minute with no allowance deducted for pipe friction, but under ordinary conditions of pipe friction the discharge from a dozen sprinklers equals the discharge from one hose nozzle. Now it is true, as Mr. Haskell said, that in a great many cases one or two sprinklers open and put out a fire. When that happens the fire department generally finds very little to do. In our fire reports, averaging more than a fire a day, we are all the time finding fires reported where two or three heads have opened and the fire has been

extinguished. Perhaps the department has had to put on a hose stream to get into a corner somewhere, but the fire was practically put out by the sprinklers.

Now in small buildings or with ordinary contents, it is true that there would commonly be only a comparatively small number of heads open. But in cotton mill work the tendency is towards very large areas. In New Bedford there are mills five or eight hundred feet long, and 125 to 140 feet wide. In such a mill it is almost impossible to reach the center with a fire hose stream, so that in such places we look upon the antomatic sprinklers as our main reliance for putting out a fire, and we feel that there is always a chance that perhaps 50 or 100 heads may open. We have had several fires in Picker rooms where twenty-five or thirty sprinklers opened in the first few minutes of the fire, and before hose streams could be put on. This was not where the pressure was feeble but where it was especially strong and able to supply large quantities without much reduction in the mains. In these cases the sprinklers did hold the fire and practically extinguished it. The only reason that so many heads opened was the quickness of the spread of the fire over loose, combustible stock. We have also had cases where seventy-five or more heads have opened.

Besides the wide buildings, there are high buildings which are sometimes quite wide besides, five or six stories and 100 feet in width not being uncommon. Here a fire in the center of the top story is very inaccessible to hose streams, so that the sprinklers are the chief reliance.

I think it will be evident to all, that any meter which in such cases cuts off several and often many pounds pressure, may seriously lessen the efficiency of the sprinklers and greatly increase the chances of a serious fire. Moreover, perfectly possible obstructions may increase the normal losses greatly or even cut off the supply entirely with some meters.

Our whole tendency is toward more liberal pipe sizes for sprinklers, meaning a chance to use larger quantities of water and within a year or two, Mr. Freeman, has advised, and there has been adopted by our companies, a schedule of more liberal pipe sizes, so that where eight or ten sprinklers are in line the most distant heads will get a good supply of water; while with the old sizes, if you open that number of heads in a line, the most distant ones will absolutely fail to get enough water to do more than drip a liberal drip.

Under these conditions you see the absolute necessity for a first-class supply. And then, remember also, that the sprinklers are the things which are working while the fire is being discovered, that is, before it is discovered, or while the department is getting there; and you will see why we feel more and more desirous, as time goes on, to make the sprinklers efficient whether few or many open at the start. In fact, our whole experience is that the very low cost of insurance in the Mutual companies is in a very large measure, due to the good work of automatic sprinklers.

THE PRESIDENT. I would like to ask Mr. French, allowing that meters are to be used, if it would not be possible to use a proportional meter, and use that with perfect safety, as far as reducing the pressure would go on the main flow of the water, even if some obstruction got into the proportional meter?

MR. FRENCH. I am very glad to have that point brought out. The proportional meter comes about as near not being a meter as anything we know of, and therefore it is the thing we like better than anything else. It, of course, puts no positive obstruction in the pipe, simply creating a little friction which operates the little meter. Now the question is, would you, superintendents, be satisfied with the proportional meter? It seems to me, as I understand your position, and I should very much like light on this point, that what you fear is the stealing of the water through the fire service pipes, either purposely or through misunderstanding. Well, now, if that is what you want to guard against, it is not going to be 500 gallons a minute, but perhaps 10 gallons a minute, or 15, or 20, and I should suppose that what you needed was something which would absolutely tell you about that thing. When it comes to larger quantities, they would hardly be used anywhere except for fire purposes, and you don't care about those. You don't charge a man for water for fire purposes, because if he don't put a fire out you have to go there and do it through another department of your government. The important thing is to prevent the stealing of water, and that is where the check valve idea seems to present a good many possibilities.

The check valve meter can be a cheap device. It gives you a proportional meter, and if you get something which will hold the clapper on the check down tight until there was a flow of 15 or 20 or 50 gallons a minute, you force all your water through the little meter and measure it accurately, but when the larger flow comes, as

from a fire draft, the check will open, and everything go on freely under ordinary conditions, or with the loss of only one or two pounds pressure, and no chance for clogging small orifices or stopping the flow entirely. Your little meter in the by-pass will meanwhile work on the proportional plan, although not recording the whole, but under those conditions you wouldn't care so much how much water was drawn. Ordinarily that little initial sticking of the check valve caused by weighting it would throw all the water to the small meter, and if you had a 10-inch service pipe, that some insurance man had somehow or other got laid into a large factory yard, you would be absolutely metering it. That is, you would have a meter on there which would be just as sensitive as if you cut that 10-inch pipe right off and put a 1-inch meter in its place. It would seem as if that would give you just the information you want, for you could go to a man and say, "You have no right to use this fire service, for you haven't had a fire, but your meter shows you have been drawing the water." He says, "How much have I drawn?" You can say, "That is not the question. You are not allowed to draw any," or you could state that at least the amount drawn was the full amount registered, and that if he had drawn it at a rate rapid enough to exceed the capacity of your (let us say) 1½ inch disc meter he had drawn in excess of the registry. And it would seem to me in that way you could keep guard over the fire system, that your interests would be absolutely looked out for, and that would be one point in your system that you knew was safe.

MR. FULLER. I would like to ask Mr. French whether a large number of small meters would not give more satisfactory results than one large meter, whether the registration would be any better?

MR. FRENCH. Of course if you had a 6-inch pipe and put in eight or ten 2-inch Disc meters you would reduce the friction to a point where even an insurance man could hardly object to it. And, moreover, by having so many openings you would, of course, very much reduce the danger of the meter becoming stuck. That is, it is very improbable that four or five would get stuck at the same time. When it came to measuring the small flows, and that is the thing I suppose you are most interested in, it would seem to me you would get no more sensitiveness than with a big meter, for the water would simply gradually find its way through each of the meters, and probably none of them would register much of anything.

SINKING FUND TABLES.

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[*Read Sept. 8, 1897.*]

As the payment of many water works debts is provided for by means of a sinking fund, it may be interesting to show how the amount required for yearly payments may be determined.

A sinking fund is ordinarily made up of annual contributions or payments, which with their accumulated interest, shall, at the end of a certain period, pay the debt for which the fund was formed.

It is evident that the longer the term which the sinking fund has to run, or in which to mature, the smaller the annual payments will be, both on account of more numerous payments and of larger accumulations of interest. Thus the annual contribution which will be necessary to pay a debt of $10,000 in ten years at four per cent, compounded semi-annually, is $799.08, while to pay the same debt in thirty years requires a yearly payment of only $170.24.

The following table shows what one dollar amounts to at the end of each six months up to the end of four years, when put at interest at four per cent and compounded semi-annually:

At time of deposit	$1.000
" end of 0 years and 6 months	1.02
" " 1 year	1.0404
" " 1 " and 6 months	1.061208
" " 2 years	1.08243216
" " 2 " and 6 months	1.1040808032
" " 3 years	1.126162419264
" " 3 " and 6 months	1.14868566764928
" " 4 years	1.1716593810022656

A similar table can be computed for any other rate, compounded either annually or semi-annually.

At the present time, four per cent, compounded semi-annually, is the common rate of interest for sinking funds.

From a table similar to the above, and computed for a period of thirty years, and carried out to a proper number of decimals, can be constructed a table showing the result of depositing or paying in one dollar each year and allowing it to go on interest at the rate of four per cent, compounded semi-annually.

The following tables are constructed for the period of 30 years, which is as long as many sinking funds run.

From this table it appears that one dollar paid in at the beginning of 30 years, amounts to $3.28103 at the end of that time. One dollar paid in at the beginning of 29 years amounts to $3.15362 at the end of that period. One dollar paid in at beginning of 28 years amounts to $3.03117 at the end of that time, and so on till the last payment, which amounts to only $1.0404, because it is on interest only one year.

If we add the amounts together, we find that the thirty payments of one dollar, with the accrued interest, amount to $58.74219. Twenty annual payments of one dollar, with accrued interest, amount to $31.11002. Ten annual payments of one dollar with accrued interest, amount to $12.51435.

This is shown in the second column of the table, which is obtained from the first by successive additions.

Now it is evident that if one dollar paid in each year, and immediately put at four per cent interest, and compounded semi-annually, produces at the end of thirty years $58.74219, that to produce $125,000 at the end of the same time, the annual payment must be equal to $125,000 divided by $58.74219, or $2,127.94.

To produce $1,000 at the end of 30 years, the annual payment must be equal to $1,000 divided by $58.74219, or $17.0235.

To produce $1,000 at the end of 20 years, the annual payment must be equal to $1,000 divided by 31.11002, or $32.1440.

The necessary annual payment to produce $1,000 in any given number of years is given in the third column of the table, which is obtained from the second, by dividing 1,000 by the corresponding number in that column.

Table Showing Debt and Annual Contribution Required for the Sinking Fund.

Year in which Debt was Incurred.	Amount of Debt.	Annual Contribution Required.	Amount of Debt.	Annual Contribution Required.	Amount of Debt.	Annual Contribution Required.	Amount of Debt.	Annual Contribution Required.	Amount of Debt.	Annual Contribution Required.	Amount of Debt.	Annual Contribution Required.	Amount of Debt.	Annual Contribution Required.	Amount of Debt.	
1885	$125,000	$2,127.94														
1886	"	"	$5,000	$453.38	$4,000	$319.63	$5,000	$355.61								
1887	"	"	"	"	"	"	"	"	$7,000	$403.64	$5,000	$160.72				
1888	"	"	"	"	"	"	"	"	"	"	"	"	$10,000	$321.44		
1889	"	"	"	"	"	"	"	"	"	"	"	"	"	"	$10,000	$3
1890	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	
1891	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	
1892	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	
1893	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	
1894	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	
1895	"	"			"	"	"	"	"	"	"	"	"	"	"	
1896	"	"					"	"	"	"	"	"	"	"	"	
1897	"	"							"	"	"	"	"	"	"	
1898	"	"							"	"	"	"	"	"	"	
1899	"	"							"	"	"	"	"	"	"	
1900	"	"									"	"	"	"	"	
1901	"	"									"	"	"	"	"	
1902	"	"									"	"	"	"	"	
1903	"	"									"	"	"	"	"	
1904	"	"									"	"	"	"	"	
1905	"	"									"	"	"	"	"	
1906	"	"									"	"	"	"	"	
1907	"	"											"	"	"	
1908	"	"													"	
1909	"	"														
1910	"	"														
1911	"	"														
1912	"	"														
1913	"	"														
1914	"	"														
1915																

The number of years the debt has to ru

WELLESLEY WATER WORKS.

n Required for the Sinking Fund.

F. L. Fuller, Civil Engineer, Boston.

Annual Contribution Required.	Amount of Debt.	Annual Contribution Required.	Amount of Debt.	Annual Contribution Required.	Amount of Debt.	Annual Contribution Required.	Amount of Debt.	Annual Contribution Required.	Amount of Debt.	Annual Contribution Required.	Amount of Debt.	Annual Contribution Required.	Amount of Debt.	Annual Contribution Required.	Amount of Debt.	Annual Contribution Required.	Amount of Debt.	Annual Contribution Required.	Amount of Debt.	Annual Contribution Required.	Total Annual Contribution Required
$355.61																					$2,127.94
"	$7,000	$403.64	$5,000	$160.72																	3,256.56
"	"	"	"	"	$10,000	$321.44															3,820 92
"	"	"	"	"	"	"	$10,000	$321.44													4,142.36
"	"	"	"	"	"	"	"	"	$6,000	$192.86	$6,000	$179.60									4,463.80
"	"	"	"	"	"	"	"	"	"	"	"	"	$6,000	$179.60							4,836.26
"	"	"	"	"	"	"	"	"	"	"	"	"	"	"							5,015.86
"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	$18,000	$578.59					5,015.86
"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	$9,000	$289.29			5,594.45
"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	$15,000	$482.16	5,883.74
"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	5,912.52
"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	5,882.19
	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	
	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	
	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	
			"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	
			"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	
			"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	
			"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	
			"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	
			"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	
			"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	
					"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	
									"	"	"	"	"	"	"	"	"	"	"	"	"	
													"	"	"	"	"	"	"	"	"	
															"	"	"	"	"	"	"	

The number of years the debt has to run is shown by the ditto marks (").

Years.	Amount obtained by compounding $1 semi-annually, at 4 per cent.	Amount obtained by paying $1 annually and compounding semi-annually at 4 per cent.	Annual payment required to produce $1,000 when compounded semi-annually at 4 per cent.
1	1.04040	1.04040	961.1688
2	1.08243	2.12283	471.0692
3	1.12616	3.24899	307.7880
4	1.17166	4.42065	226.2111
5	1.21899	5.63964	177.3163
6	1.26824	6.90788	144.7622
7	1.31948	8.22736	121.5457
8	1.37279	9.60015	104.1650
9	1.42825	11.02840	90.6750
10	1.48595	12.51435	79.9083
11	1.54598	14.06033	71.1221
12	1.60844	15.66877	63.8212
13	1.67342	17.34219	57.6628
14	1.74102	19.08321	52.4021
15	1.81136	20.89457	47.8593
16	1.88454	22.77911	43.8999
17	1.96068	24.73979	40.4207
18	2.03989	26.77968	37.3417
19	2.12230	28.90198	34.5997
20	2.20804	31.11002	32.1440
21	2.29724	33.40726	29.9336
22	2.39005	35.79731	27.9351
23	2.48661	38.28392	26.1206
24	2.58707	40.87099	24.4672
25	2.69159	43.56258	22.9555
26	2.80033	46.36291	21.5690
27	2.91346	49.27637	20.2937
28	3.03117	52.30754	19.1177
29	3.15362	55.46116	18.0306
30	3.28103	58.74219	17.0235

A water works or town debt is generally made up of several issues of bonds or notes. These bear different dates, are for various amounts, and run for different periods of time.

The contribution for each issue must be computed separately and the sum of these contributions will be the annual contribution required to form a sinking fund capable of meeting the various obligations as they become due.

DISCUSSION.

THE PRESIDENT. It is well known to all of us that water works men know more about almost anything connected with water works than the financial part. The financial part of the department, the control of the sinking funds and everything in that connection, is usually turned over to some commission or some members of the

city government, and, while I suppose they always exercise good judgment in the way they handle the sinking funds, it has often occurred to me as very remarkable that it is so seldom they invest any of their funds in buying their own city's bonds. Most cities have to issue bonds, have to hire money, and I have often thought it would be a wise plan for a city to borrow of itself.

MR. FULLER. I would like to say in that connection, Mr. President, that the sinking fund of the town of Wellesley amounts to about $60,000, and that is entirely invested in the securities of the town of Wellesley. Of course it may not be possible to continue that practice, but, as Mr. Haskell has said, I think it is a good one.

MR. SMITH. I have had some experience as water commissioner and also as water superintendent in one of our small towns, where we have a debt of $75,000. The difficulty of investing the amount of money which is required for the sinking fund, is one which is somewhat perplexing. We could not buy securities with it, because the amount was so small. We have found that the best way, in order to secure compound interest on it, is to deposit it in the savings bank. In that way we have no trouble whatever; there is no money to be handled, we put in each year just the amount of money we calculate is required to make the exact deposit in the savings bank, and we let it remain there until our bonds become due, and then we draw from the savings bank whatever money is required to pay them.

As I say, we have a debt in our town of $75,000. I was very strongly advised against establishing a sinking fund at all, and it was recommended that it would be very much wiser to have annual payments, doing away with a sinking fund entirely and paying so much a year. The difficulty there was we would have to divide our whole debt up into sums of money so small that capitalists would not care to purchase the securities. It was necessary to have our debt divided up into thousand dollars. We finally made an arrangement so our debt should become due in installments of five years each—a certain number of bonds—the first five years, the next five years a larger number, and so on. The last five years of the thirty,—they were divided into six different series,—quite a large sum would become payable, but the interest, of course, is constantly decreasing with the debt. Our act of incorporation required us to establish a sinking fund, and the fact that the bonds were not to be paid

in annual payments created a necessity for a sinking fund, and in order to provide means for paying the installments as they became due, we deposited our money in the savings bank.

MR. GILBERT. In our town we have placed the sinking fund in our own water bonds wholly. We began in that way and have always kept it up, so our sinking fund consists of our own water bonds. They pay four per cent and we have taken them at par.

MR. FULLER. I would like to ask Mr. Smith what rate of interest he gets?

MR. SMITH. We usually get four per cent, and our bonds bear interest at four per cent. I ought to say, perhaps, what I omitted to say, but my friend has brought it out by the remarks he has just made, that we virtually invest in our own bonds, because every five years we take up a certain number of the bonds. Then the next five years we have to make a deposit in the sinking fund large enough to cover the interest on those bonds we have redeemed.

MR. BEALS. I have had a little experience with sinking funds and with water debt, but not in the line of the practice of the gentleman who spoke last. I do not understand how he can get interest from a savings bank on more than $1,600, for our Massachusetts savings banks can only receive a deposit up to one thousand dollars and pay interest on sixteen hundred dollars. If they pay on more than that I suppose they are liable to be called to account by the bank commissioners. We have in our town a debt of the size he mentioned, $75,000. We commenced at first by making it payable in blocks of a certain amount at the end of each five years. After running a little while we found just that difficulty of finding an investment for our sinking funds. The savings bank would take only a thousand dollars, and we could not find investments, and we began to see thousands of dollars piling up. Now to an average water man five thousand dollars is a big sum, I mean to those of us connected with the smaller works, and we saw that the whole thing was rather a menace. There was a temptation, an itching desire, perhaps, to handle large amounts of money. And right here I may say it seems to me that the paying of a debt with a sinking fund is like constituting ourselves bankers. It is doing a double business to accomplish a single purpose. That is we reckon how much we owe, and how much we are getting in our sinking fund, and there are two funds piling up.

After running one year we found there was this temptation, the difficulty of finding investments, and the risk of having some board or commission handling the sinking fund, and necessarily some salary to be paid to somebody to handle it, which would be an expense. Our bonds were all held by one savings bank as an investment. So we obtained the permission of our fire district which owns the works, and of the bank holding our bonds, to alter our times of payment, and we made thirty different bonds, payable in different sums in the thirty years. When our act was passed we were required to establish a sinking fund, and at that time we voted to establish a fund to which we would contribute every year an amount sufficient to pay the bonds maturing at the end of each five years. We changed our bonds so that we made a bond payable every year. The first five years of the thirty we paid a thousand dollars a year. Then at the end of that time, if we had paid five thousand dollars we saved two hundred dollars in interest, and we calculated our works would be increasing in the meantime, and our receipts increase, so that in the second five years we could pay fifteen hundred dollars each year, and the third five years two thousand dollars, and I think the fourth five years we jumped to three thousand dollars, and then thirty-five hundred dollars, and then four thousand. We find we can keep a deposit of about a thousand dollars in the savings bank, but we hardly need to. We are on our twelfth year now, so we are required to put two thousand dollars into the sinking fund each year. There are two times in the year when a certain extra receipt comes to us, and we put that into the sinking fund. The first of September our bonds become due, and we draw an amount equal to the bond, and have something left all the time. Our sinking fund is never very large, and there is not the temptation for any board of officers handling a big sum of money, and we, as water commissioners and trustees of the sinking fund cannot get away with a very big sum if we wish to. We have protected the district, and got the sinking fund into a state of annual payments, where we handle only just about the money that we earn, and save, and expend towards the payment of our debt. The ordinary sinking fund is just like an individual hiring twenty thousand dollars for a certain purpose, and then going ahead and trying to lay up twenty thousand dollars somewhere else to pay what he has borrowed. He risks in two ways. He risks ever being able to pay the twenty

thousand dollars, and he risks losing the money he is laying up. It is a wise and safe rule for municipalities as well as for individuals, "If you have a dollar pay your debt with it."

MR. CODD. I would like to ask the gentleman (Mr. Gilbert), if, when he buys his own bonds, he cancels them?

MR. GILBERT. I will say that, unfortunately, the men who established our debt issued the bonds, so they are all payable in so many years, and therefore we are compelled to keep them.

MR. CODD. So each year you have to raise interest on them and pay it to yourselves?

MR. GILBERT. We clip the coupons and collect the interest ourselves. We know that is not the right way to do, but the bonds are thirty year bonds, all payable in thirty years to the amount of one hundred thousand dollars.

MR. HAWLEY. It occurs to me that in issuing bonds the money is used for various purposes. Sometimes it is used for laying pipes or doing work which will last for a long term of years, and again the money is used for pumps, or for some working part, which will wear out in a shorter period of years. And yet it seems to be a rule, at least in this country, to issue bonds for a period of about thirty years, without paying any attention to the purpose for which the money is to be expended, whether it will give returns for thirty years or whether it will give returns for a longer period. I would like to ask Mr. Fuller if he has looked into this matter, and can give us any reason why this period of years is taken, instead of a period of years during which the work for which the money is spent will give a return?

MR. FULLER. I don't know that I did take into account what the gentleman has suggested. I simply made this tabulation to cover any period from one to thirty years. Of course it could be extended to a good deal longer time by simply adding to the figures. I don't think Mr. Smith answered the question Mr. Beals suggested, with regard to amount he could put in any one bank.

MR. SMITH. I will simply say in reply to that, that the amount we are required to raise for our payments at no time exceeds perhaps twenty thousand dollars. The amount actually deposited in the savings bank I would say would not exceed at any time ten thou-

sand dollars, for the money the last year would be paid towards the debt directly, and it would not be necessary to invest it. I live in a town near a large city where we have access to six or seven different savings banks. All of them are equally good and equally safe, and by depositing a thousand dollars in each bank and allowing it to accumulate to sixteen hundred dollars, we should have in those banks the full amount of ten thousand dollars. The principle I have advocated is precisely the same as has been stated, only the periods are a little longer. If this method of investment is to be followed, it is of course necessary that the amount to be deposited should not be too large. The principle only applies to the smaller towns, where, as I may say it is almost a nuisance to manage a sinking fund.

RESULTS OBTAINED BY THE INTRODUCTION OF THE METER SYSTEM AT ATLANTIC CITY, N. J.

BY W. C. HAWLEY, C. E., ASSOCIATE MEMBER A. S. C. E.

[*Address Sept. 9th, 1897.*]

Atlantic City, N. J., is located on a long, narrow, sandy island, no part of which has an elevation of more than 12 or 15 feet above high tide. Its population ranges from 21,000 in winter to over 175,000 some days in summer. There is no manufacturing, but there are over five hundred hotels and large boarding houses, and about two hundred smaller boarding houses. There is a system of sanitary sewers, the storm water being carried off in the gutters.

In 1882 the Atlantic City Water Co., constructed a system of water works and began to furnish the city with water from the mainland, about six miles distant. From the first there was friction with the city government, and in 1888 the "Consumers" Water Co., constructed a plant and began furnishing water from artesian wells on the island. These two companies consolidated in 1893, and in 1895 both plants were purchased by the city, and have since been operated by a board of commissioners.

During the period of competition between the two companies, waste was encouraged rather than prevented. Many of the cheaper class of houses were on piles or stilts with pipes exposed underneath; and a few days of cold weather would cause an increased pumpage amounting to from 10 per cent to 30 per cent of the normal. Hopper closets were in common use, and the plumbing in a large portion of the less expensive buildings was of the poorest sort. Some meters had been used, but a large bill by meter measurement was frequently the reason for the removal of the meter, instead of the stoppage of the waste. The consolidation of the two companies made little change, as the prospect of purchase by the city was sufficient to defer all improvements.

When, on August 1st, 1895, the city took possession of the works, it was impossible to maintain a pressure of over 20 to 25 pounds during much of the summer season, and the plants were being operated to their limits. The consumption per capita ranged from 200 to over 250 gallons per day. Parts of the city had either no water mains at all, or else those in place were so small as to furnish but little supply. A large amount of pipe was needed in these districts, and when laid, more water would be needed to supply them. The problem confronting the city was either to reduce the enormous waste, or else to provide an additional supply of water, with new pumping plant and mains at a cost of at least $250,000, with the additional cost of operating and maintaining.

Mr. George T. Prince, member of A. S. C. E., who was appointed superintendent when the city purchased the works, recommended the general introduction of water meters and certain extensions of the distributing system. After consulting with Mr. Clemens Herschel, member of A. S. C. E., it was decided to spend $75,000 at once on extensions of the distributing system, and about 16 miles of new mains were laid; also to spend $25,000 in purchasing and setting water meters, the expenditure of $250,000 for a new supply, pumps, force mains, etc., being deferred until the results of the introduction of meters should be known.

The writer was appointed superintendent to succeed Mr. Prince, March 1st, 1896, just as the first of the meters were set. There were at that time about three hundred meters in service (many of them old meters, worn out and practically worthless) on a total of 3,095 taps. On August 1st, 1896, there were 1,916 meters in service on a total of 3,446 taps. August 1st, 1897, there were 2,135 meters in service on a total of 3,692 taps.

The results are shown in the diagrams. Fig. 1 shows the pumpage by months since the works have been operated. Fig. 2 is a comparison of the pumpage profiles for the years 1890–1897 inclusive. It is probable that about 10 per cent of the reduction in pumpage shown is due to improved condition of the pumping machinery and a slightly larger percentage for slip than was formerly allowed. Note should be taken of the fact that on August 1st, 1895, the number of services was 3,095. On August 1st, 1897, the number of services had increased to 3,692, or 19.3 per cent. In spite of this, and almost entirely because of the reduction of waste, the

Pumpage Diagram Atlantic City Water Dept.

Mainland Station July 1882 to Sep. 1896

Consumers " Nov 1889 " "

Showing Gallons per month.

1st of Mainland Station.

2nd " Consumers "

3rd " Total of both Stations

N.B. Consumers Station not run during months of January and February 1896. Pumpage for Consumers Station for June to December 1895 were estimated. Since no record was kept. Consumers Station was started up in June 1888 but no record was kept until November 1889

Millions of Gallons.

300

250

200

150

100

50

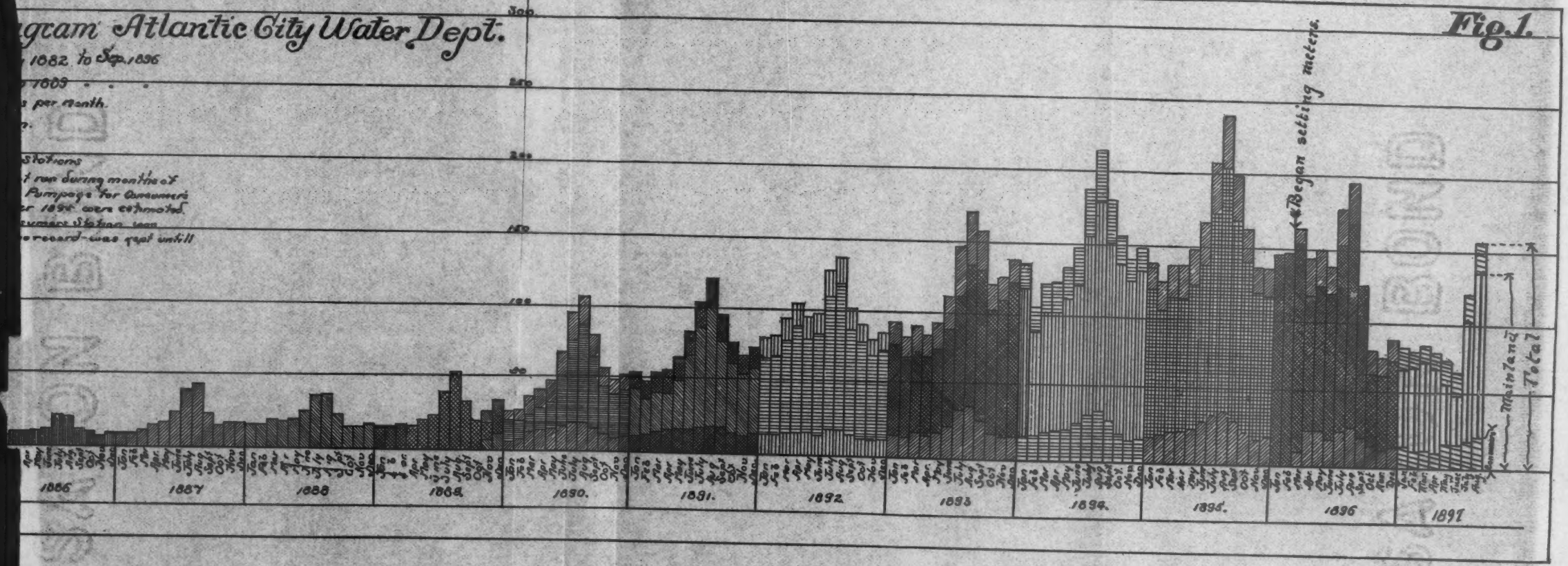
0

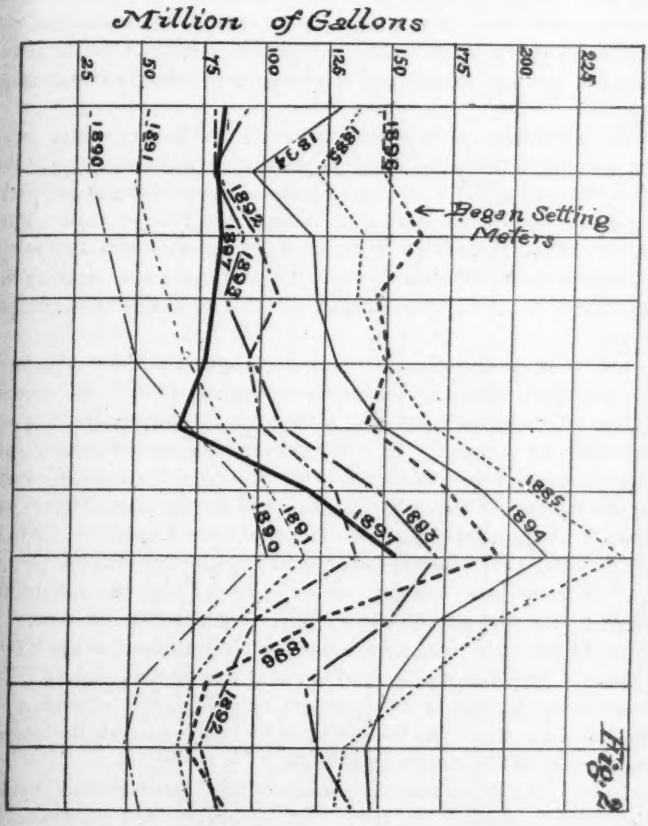
1882 1883 1884 1885. 1886 1887 1888 1889

gram Atlantic City Water Dept.

1882 to Sep. 1896
1889 . . .
s per month.
n.
Stations
t run during months of
Pumpage for Consumers
r 1894 were estimated.
nearest Station was
o record was got until

Fig. 1.





pumpage shows a very marked reduction. It is true that during this period five of the larger hotels put down artesian wells for their own supplies, but the total reduction in pumpage on this account would not exceed 100,000 gallons per day; and the reduction in pumpage in August, 1897 over that of August, 1895 was 2,700,000 gallons per day. The average number of gallons pumped per tap per day in August, 1895, was 2,500. In August, 1896 this was reduced to 1,775 gallons; and in August, 1897 to 1,350 gallons, or a reduction of 46 per cent from August, 1895. This reduction in

pumpage enabled the ordinary pressure of 35 to 40 pounds to be maintained during the summer months, something which had not been done before in several years and this in spite of the large increase in the pipe system and the consequent additional consumption.

The immediate result of the introduction of meters was to defer for some years the necessity for expending for additional supply the $250,000 contemplated, thus saving the additional interest and sinking fund charges, amounting to at least $16,250 per year. THIS SAVING ALONE IN LESS THAN FOUR (4) YEARS WILL BUY AND SET A METER ON EVERY SERVICE IN THE CITY, and this allows nothing for the saving in extra labor, salaries etc., for operating the enlarged plant.

Fig. 3 shows the diagram of coal consumed at the "Absecon" (or mainland) pumping station since August, 1893. The records of the "Consumers" pumping station are incomplete and can not therefore be included. This shows a decided saving in coal consumed, due as before explained to the reduction in pumpage caused by the meters. Comparing the coal used for the year, August 1st, 1894, to August 1st, 1895, with that used from August 1st, 1896, to August 1st, 1897, there is found an average saving of 2,500 pounds (1.115 gross tons) per day, which at $3 per ton, the cost of the coal in bin, is worth $3.34 per day, or $1,220.93 per year. To this add one-sixth as much to allow for coal consumed at the "Consumers" pumping station, and the total saving is $1,424.41. The interest on the cost of these meters (including cost of setting) is $1,125 per year, so that the saving in fuel alone exceeds the interest on the cost of the meters by $299.41.

It has been shown that the number of taps increased from August 1st, 1895, to August 1st, 1897, 19.3 per cent. Had it not been for the introduction of the meter system it is reasonable to suppose that the additional fuel needed would have been at least an equal percentage, (admitting for the moment that the increased pumpage was within the capacities of the plants, which it was not). This increase would have amounted to $1,244.28 per year, to which add $299.41 (the saving per year already shown in fuel over interest) and the sum—$1,543.69 is more than enough to pay the cost of maintenance and care of the meters—which is about $1,400. This calculation has taken no account of the additional revenue received

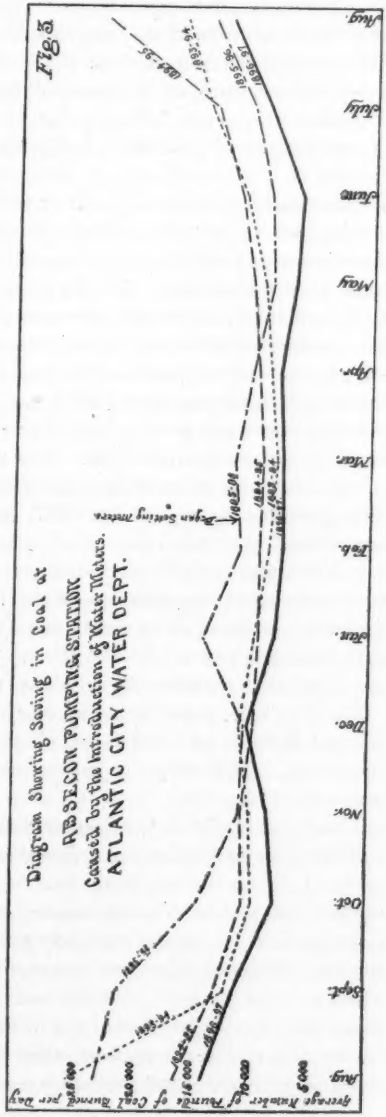


Fig 3
Diagram Showing Saving in Coal at
ABSECON PUMPING STATION
Caused by the introduction of Water Meters.
ATLANTIC CITY WATER DEPT.
Began Setting Meters
Average Number of Pounds of Coal Burned per Day
Aug.
Sept.
Oct.
Nov.
Dec.
Jan.
Feb.
Mar.
Apr.
May
June
July
Aug.

from the 597 new services, which is easily $10,000 per year. This increase is probably offset however by the decrease in revenue due to the very general saving to the consumers on the meter rate, compared with what they formerly paid on the assessed rate. This reduction of bills has made the meters quite popular, though there is still occasionally heard the wail of some one who did not have repairs made when he should.

It becomes evident therefore, that considered solely as a cold blooded business proposition—not taking into account the equity, justice and other good reasons for its introduction—the meter system in Atlantic City has proved a success. We are now setting 1,000 new meters, and the intention is to ultimately meter every service.

The city council has decided to raise by direct taxation each year a sufficient sum to pay the water department for the water used for fire protection, street sprinkling and other public uses, thus making all property pay directly for these services, in addition to the payment for water actually used on the premises. This allows a lower meter rate than would otherwise be possible—12 cents per thousand gallons. The rates previous to August 1st, 1897, were 18 and 14 cents per thousand gallons.

In connection with this paper, the writer wishes to mention some matters which have come up in connection with the use of meters in Atlantic City which may prove of interest, and which he hopes will call forth some discussion:

FIRST—In introducing meters generally in a city where the assessed rate has been the rule, there is bound to be more or less "kicking" on the part of those who find their bills increased when what is used is measured. This can be largely avoided, and in all fairness and reason should be.

Our meters were as a rule placed on services some weeks previous to the expiration of the term paid for on the assessed rates. Shortly before rendering the bills for the minimum rate in advance, the meters were read, and with a slide rule the number of gallons used per day on the average, for each service, was computed. This was stated on each bill, and if the amount was excessive the consumer was cautioned when he paid the bill. At the end of the first six months it was found that about one-third of the meters had registered in excess of the amounts of the assessed rates formerly paid; one-sixth were practically the same, and one-half were saving money.

Of course there were some protests, and where waste had occurred without the knowledge of the owner, some rebate was given. At the end of the first year it was found that very few still had excessive bills, they had stopped the leaks and waste, and now it is impossible to supply meters fast enough to meet the demand.

SECOND—One of the primary reasons for the introduction of the meter system is to prevent the waste of water. It is therefore desirable to locate the places where the greatest leakage or waste occurs, that such may be the first to be metered, and thus the maximum saving effected with minimum expenditure. A common opinion exists that the greatest waste occurs in the better class of buildings, where fixtures are more numerous; where lawns are sprinkled; where large washings are done; where bath tubs are frequently used, etc. Our experience in Atlantic City does not bear out this theory. We find that one leaky hopper closet (or one that is allowed to run continuously) in some small property that paid perhaps $6 or $8 per year on the assessed rate, will waste water enough to supply half a dozen fine residences, and sprinkle an acre or two of lawns besides —that the stop and waste in a cheap house where it is necessary to shut off the water every cold night to prevent freezing of the pipes, will soon wear and leak, (in this sandy soil) till five or six of them would waste enough water to do the laundry work of the town—that in cheap houses or where there is cheap plumbing, by letting the water run to prevent freezing in cold weather, enough is wasted to furnish baths galore for the whole population. In other words the great bulk of the waste is in the smaller and poorer properties. Of course there are exceptions like manufacturing plants, hotels, saloons with beer pumps, motors, etc., and occasionally we find waste in the better class of houses; but our experience indicates that with a limited amount available for meters, more waste can be stopped in tenements and the cheaper class of dwellings than anywhere else.

THIRD—What tests should be specified for water meters? Our first meters were purchased under the requirement that "no meter shall over-register, and no meter shall under-register more than two (2) per cent."

All meters of $\frac{5}{8}$-inch and $\frac{3}{4}$-inch sizes had to register on a $\frac{1}{32}$-inch stream; 1-inch on a $\frac{1}{16}$-inch stream, and larger sizes on a $\frac{1}{8}$-inch stream. Later specifications have required an average of the larger

streams down to and including the $\frac{1}{8}$-inch to be within the limits of 625 pounds and 630 pounds on a registration of 10 cubic feet, no single test to exceed the limits of + 1 % and — 2 % (618$\frac{3}{4}$ pounds and 637$\frac{1}{2}$ pounds); $\frac{5}{8}$-inch and $\frac{3}{4}$-inch meters to test on $\frac{1}{16}$-inch and $\frac{1}{32}$-inch streams within + 1 % and — 5 %; the 1-inch meters to test within the same limits on $\frac{1}{16}$-inch stream; and 1$\frac{1}{2}$-inch meters to test within the same limits on a flow of 1$\frac{1}{2}$ cubic feet per hour. These tests are made under a pressure of 35 to 40 pounds. The testing is expensive, and it has occurred to the writer, that more simple tests might do as well, so far as practical results are concerned. Possibly on the $\frac{5}{8}$-inch, $\frac{3}{4}$-inch and 1-inch sizes a close test on a $\frac{1}{4}$-inch stream, say between the limits of 625 and 630 pounds on 10 cubic feet for accuracy; and a test on a $\frac{1}{32}$-inch stream for $\frac{5}{8}$-inch and $\frac{3}{4}$-inch meters, and on the $\frac{1}{16}$-inch stream for 1-inch meters, with somewhat wider limits, say 618$\frac{3}{4}$ (+ 1 %) and 675 pounds (— 8 %) on 10 cubic feet registration for sensitiveness, would be as satisfactory as a more extended series of tests. The practical value of any test can only be told by observing the operation, in service, of the meters purchased under it.

This matter of testing meters deserves more attention than has been paid to it. A series of standard tests should be adopted and generally used. Varying conditions would have to be met by varied tests; but the conditions in this country are not so diverse but that a series of tests could be arranged which would be practical, satisfactory, and not too expensive.

FOURTH—The meters in use when the city purchased the plants were practically all of the "rotary" type. The first meters purchased by the city were largely of the "disc" type, though all the 1$\frac{1}{2}$-inch, 2-inch and 3-inch meters purchased were rotaries, and a few 1-inch and $\frac{3}{4}$-inch meters. It was found that the smaller rotary meters were more frequently "stuck" than the disc meters. Also that those that had been in service five or ten years were underregistering from 10 per cent to over 90 per cent; and some of them were "stuck" almost every time they were read. Several of the worst of these meters had already been repaired two and three times, at a total expense equal to if not exceeding the cost of a new disc meter. It was found that after being repaired and brought up to correct registration once, the rotary meter gets out of repair much quicker than it did the first time. The department is there-

fore spending very little money on repairs to worn out rotary meters. If simply renewing a worn out part, or some little shop work will put a meter in good condition, it is done. Otherwise it goes into the scrap heap. It is believed that considering the increasing frequency and cost of repairs to rotary meters, and the loss of revenue due to under-registration, it is better policy to replace them with disc meters than to try to keep them in repair. The disc meters cost less, and even if they show equal wear in equal time, which there is no reason to expect, the working parts can be renewed for less than the working parts of rotary meters. The friction for full flow in rotary meters is greater than that in disc meters of the same size, which is an objection where the pressure carried is low, as in Atlantic City. It is also found that the rotary meters are not as sensitive, that is will not register as accurately on the small flows, as the disc meters.

All things considered therefor, it seems best to give preference in the future to the disc type of meter in Atlantic City. Different conditions elsewhere may give different results. It would be interesting to know what results have been obtained in other places. and the writer hopes that the discussion of this paper will bring out the experience and views of others.

STEEL FORGINGS FOR PUMPING ENGINES.

BY H. F. J. PORTER, M. E.

[*Read and Illustrated by Stereopticon, Sept.* 9, 1897.]

So vast is the whole field of engineering that it is beyond the capacity of any one man to cover all of it, and so the profession is subdivided into specialties, one of the most important of which is that of the water works engineer. So comprehensive in itself is this subdivision, necessitating a knowledge of many of the other specialties, that much time and labor must be devoted to keeping up with the progress which is being made in them. If, therefore, some one who devotes his time and attention in one of these contributary directions will present to the water works engineer in a concise form some of the information that the latter would otherwise have to go possibly far out of his way to obtain, the saving in time and labor should come to him acceptably. My excuse, therefore, for drawing on metallurgical engineering for my topic must be that in the multiplicity of your other researches you might not otherwise secure in a handy form for reference the information which I will endeavor to present to you, and which I trust will be of service.

It will not be necessary for me to refer to the constantly growing responsibility which the water works engineer has to assume in designing a municipal pumping-plant. For the money it has invested freely, the public looks to him for a supply of water that never fails for even an hour.

Not only does the safety of property depend upon an efficient fire protection, but many enterprises require an uninterrupted flow of water, and health itself is assured only through the knowledge that cleanliness can be depended upon.

Every detail of your machinery must be of the most approved design and of the best material, lest it fail at a critical moment.

As our cities grow in population demands increase for larger units in our pumping stations, and it is in the nature of large pieces

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NOTE.—A paper similar to the above was presented at the annual meeting of the American Water Works Association held at Denver, Colorado, June 9, 1897.

At the suggestion of several of the members of this Association, Mr. Porter was requested to repeat the paper. The paper as presented is like the original in all respects, except that a few additions have been made to the specifications quoted, bringing it up to date. [Editors.]

of metal, such as are necessary for the component parts of large engines, that, as they increase in size, they are more difficult to make with a certainty that they shall not be defective. The high duty called for in certain localities requires that all parts of such pumping-engines shall be unusually strong.

In such engines, speaking generally, all moving parts and all parts that may be subjected to alternating stresses are made of forgings, and it is to these that I desire to direct your consideration.

In the minds of those who have not given the subject some investigation, a forging is "a forging" simply. The name signifies that the piece has not been cast but has been worked up, somehow or other, under the hammer. Of what it is made, whether of iron or steel, and of what quality of either metal, seems to be of no moment.

That these unconsidered characteristics are, from the changing conditions of the times, becoming of greater and greater importance, I think I can convince you if you will give me your attention while I briefly review the history of the development of the art of forging in this country.

Up to thirty years ago wrought iron was the metal of which nearly everything in the nature of a forging was made. Rolling mills were turning out rails, structural material and merchant bars of wrought iron, and there was plenty of wrought iron scrap of good quality in the market from which forgings could be made. The industrial conditions of the country, however, were such that forges were not called upon to produce forgings of very great size. Those for which a demand was made could readily be built up by welding together small pieces of wrought iron under comparatively light hammers.

About this time, however, the large rolling mills began to change their product from wrought iron to steel, first turning out rails and structural material, later, merchant bars, and subsequently plates. As the manufacturers of the country became more and more familiar with the use of the new material, they began to appreciate that they were getting something that was stronger and more reliable than what they had been accustomed to, and, realizing that they could reduce the sizes of the forged parts of their machinery by using steel, soon began to call for steel forgings. Those that they obtained, however, were far from satisfactory, and with reason, for

the forges had not equipped themselves properly for turning them out. A little explanation may perhaps be necessary.

An iron forging is built up of small pieces and advantage is taken of the property of welding which iron possesses. A steel forging, on the contrary, has to be made from a steel casting larger than the finished piece, as steel does not possess in the same degree the property of welding. It should be, in fact, twice its size in order that the amount of work necessary to make it a forging may enter into the metal during its reduction in size under the hammer. For instance, if you should want a 12-inch shaft, made of iron, it would be built up of small pieces, 4 or 5 inches thick, welded together. If, on the contrary, you should call for a steel shaft of the same size,

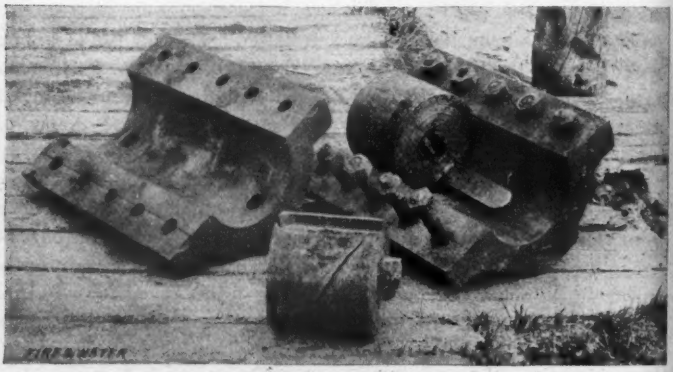

FIG. 1.

best practice would require beginning with a piece of steel 24 inches in diameter and forging it down under a hammer the blow of which could be felt through 24 inches of metal instead of only 4 or 5 inches, as in the case of iron; so you can readily see that, when the manufacturers called for steel forgings, the forges did not have the hammer equipment necessary to make them, and there were many other reasons for their inability to supply what was wanted, as you will appreciate when we view the processes which are now considered necessary for turning out good work. Many forges did not hesitate to supply, however, so-called "steel forgings," and, although they have never fitted themselves up prop-

erly to this day, they have not hesitated to continue to supply the same thing ever since; but what has been supplied has not been, and cannot be, satisfactory, as I think I will make clear to you as we go further into the subject. The result is that a prejudice has unjustly been established in the trades against steel, and it has been kept fresh in the minds of the uninformed up to the present time to a great extent through these forges themselves, who have been unwilling to spend the necessary amount of money to equip themselves properly for turning out steel forgings.

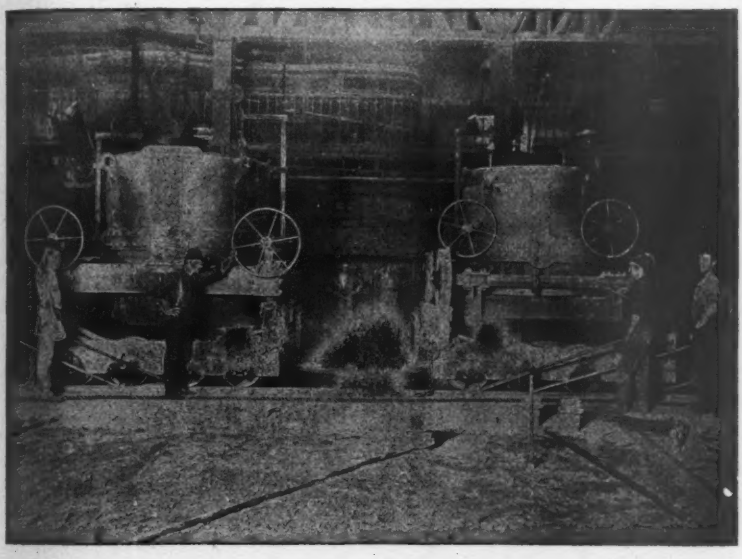

FIG 2.

Since this time, the change from iron to steel in the rolling mills of the country has become almost complete, and today wrought iron scrap is becoming more and more scarce and steel scrap more and more plentiful, so that it is with difficulty that wrought iron forges can prevent pieces of steel scrap from getting into their wrought iron forgings, for there is no way of identifying a piece of steel scrap by sight. When steel gets into a wrought iron forging, it does not weld up with it and causes points of weakness which event-

ually lead to fracture. Fig. 1 shows a wrought iron shaft broken from this cause. The piece of steel can be seen projecting from one piece of the shaft.

Good wrought iron in moderate sized forgings has an elastic limit not higher than 20,000 pounds to the square inch, on account of the large amount of slag and scale which is inherent in the metal owing to its having been puddled, in process of manufacture, in a bath of liquid cinder. Steel, on the contrary, from which the slag has escaped during its melting process, has in its mildest form an elastic limit of about 30,000 pounds, and is therefore at least one-third stronger. For these reasons steel is rapidly driving wrought iron out of the market altogether, and engineers who fully appreciate the situation have already given up the use of iron entirely. Forges are gradually equipping themselves for turning out steel forgings properly, there being one forge in this country which is probably the most complete in the world.

Let me run rapidly through the processes which are considered the best practice for turning out steel forgings.

Fig. 2 shows a small section of a furnace-plant and represents the casting of an ingot. On an elevated shelf are located a series of open-hearth furnaces to which the various ingredients of the charge to be melted are raised on hydraulic lifts. Into these furnaces (which are heated by gas generated extraneously) can be put such a composition of steel as will give the type of forging which is required for the service to which it is to be subjected eventually. Thus from ten (0.10) to fifteen hundreds (0.15) of 1 per cent of carbon make a grade of steel that differs but little in its strength from wrought iron, while an increase in its percentage up to a certain limit tends to make it stronger, and, beyond that, hard and brittle. Too much phosphorus tends to make it brittle when cold, and sulphur to make it so brittle when hot that it cannot be forged properly. Steel of high grade should have not more than .04 of 1 per cent of these elements in it. Others of its chemical constituents affect it in similar and other ways. Their combination in proper proportions can be arrived at only from long experience in constant handling, and by observing their subsequent effect on resultant forgings in actual service. From time to time, during the process of melting, a small dipperful of the molten metal is taken out of the furnace and rapidly tested, to ascertain how the refining is tak-

FIG. 3.

ing place, and when the charge is ready the metal is poured from the furnaces into ladles, which in turn empty into moulds located in the casting pit underneath.

Fig. 3 shows an end view of this pit. Here is a mould in which steel is supposed to have been poured from the ladles shown in the previous picture. Moulds of this character are from two to six feet in diameter and are built up in sections to any desired height. In order to make a forging properly, the best practice requires that an ingot be cast about twice its diameter, in order that sufficient work may be put into the original casting during the forging process to give the metal strength and toughness. Besides this increase in diameter a certain amount is added to its length, for reasons which I will try to make apparent to you.

There are various defects which are inherent in steel castings. In the first place, when pouring metal into the mould, air is apt to be entrained and cause blow-holes. In the next place, at certain stages of the cooling process gas is generated and will cause blow-holes of itself. There are several ways of overcoming these defects, but without doubt the most efficient is what is known as the Whitworth process of "fluid compression." In this the mould is placed on a platen and slid underneath an hydraulic press. (Fig. 3.) This press has a capacity of 7,000 tons, and under this enormous pressure the air which has been entrained in the pouring is forced out through joints in the mould where vents have been left for that purpose, and the gases which are apt to form in the cooling of the mass are prevented from generating.

Another defect, which is apt to occur in an ingot is known technically as "piping." The metal, when it is poured into a mould, cools and solidifies first at the surface of the mould, and as the solid metal keeps cooling towards the center it shrinks and draws away from it. We have, if you can imagine such a thing, a pot with metal in it which is really not sufficient to fill it properly, but which is being drawn out in all directions to fill it. This shrinkage draws principally from the center and the top, these being the parts that solidify last. It is, therefore, to take care of this shrinkage that more metal is added to the length of the ingot than would otherwise be required. The hydraulic pressure applied at the top forces the fluid metal from this added part down through the center, and

thus we are enabled to keep the latter filled where otherwise we would have a cavity or "pipe."

Still another defect which is apt to occur in ingots, and especially in those of very large size, is what is known as "segregation." This is partly a mechanical and partly a chemical separation of the various ingredients of steel (sulphur, phosphorus manganese, silicon, etc.) each of which has its own temperature of cooling. As the mass cools the tendency of these ingredients is toward the central and upper portions, where it cools last, thus forming a central core of impurities. This does not occur to such a great extent in small

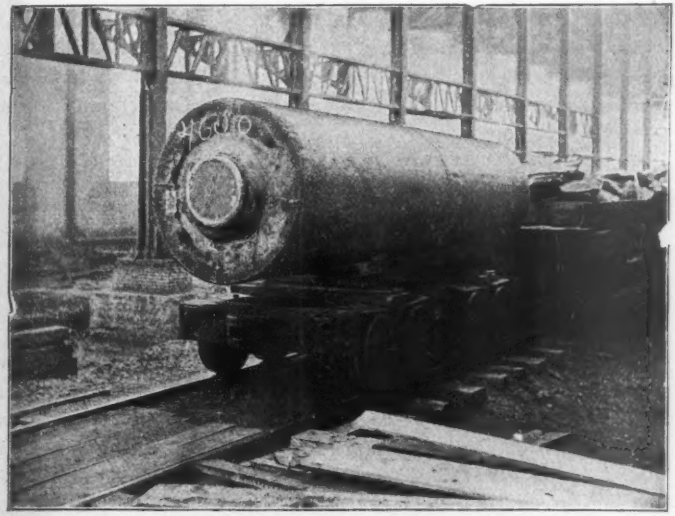

FIG. 4.

ingots, but in all large ingots it does occur, and even this process of fluid compression does not entirely prevent it. But it does succeed in giving us a perfectly solid piece of steel, with the exception of segregation in large ingots, and that defect, I will show later, can be taken care of. It is necessary that we should have an absolutely solid ingot at the beginning, because steel will not weld, and, if we have any defects in the ingot to start with, they cannot be remedied later by hammering, as might be the case if we were dealing with

iron, which, owing to the slag in its composition, as previously stated, possesses the property of welding.

Fig. 4 shows a fluid compressed steel ingot after being taken from the mould. It is twice the diameter of the forging to be made from it, and has considerable extra metal at its top to take care of piping and segregation, as already mentioned. This extra length, having served its purpose of supplying metal to fill blow-holes and pipes, and of collecting segregation, is cut off and returned to scrap, and the ingot is then ready for the forging process.

The first operation in the process of forging is the reheating of the ingot. This operation is a very delicate one, as great care must be taken to make the heat penetrate the metal slowly and uniformly.

As I have already told you, the metal in the ingot during the process of cooling is being drawn out in all directions to fill the mould. When it is cold, therefore, it is in a condition of strain

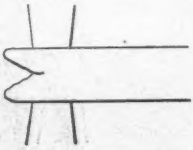

FIG. 5.

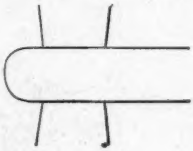

FIG 6.

throughout its interior. Now, if we put a cold ingot into a furnace to be reheated, we immediately expand the surface metal and pull it still further from the center, thus putting an additional strain on the metal inside. In very large ingots cracks are thus apt to be started in the center, and forgings are very liable to break in subsequent service from the fact that they have not been properly reheated. This process is not considered of sufficient importance by forges generally, and a great many forgings fail from lack of care being taken at this time.

Now comes the forging process proper, and one of the first requisites is the proper selection of forging tools. The pressure applied in shaping a piece of steel should be of sufficient power and of such a character as to penetrate to the center and cause flowing throughout the mass. This flowing of the metal requires a certain amount of time, and the requisite pressure should be maintained throughout a corresponding period.

Fig. 5 shows the effect of forging a large shaft under a light hammer. The blow is made very quickly, forced by top steam, so that the metal has not sufficient time to flow and all that has been accomplished is damage to the surface metal without any effect whatever being produced on the center. There is a tendency to draw the surface metal away from the center, and on all large shafts which have been forged under light hammers will be found

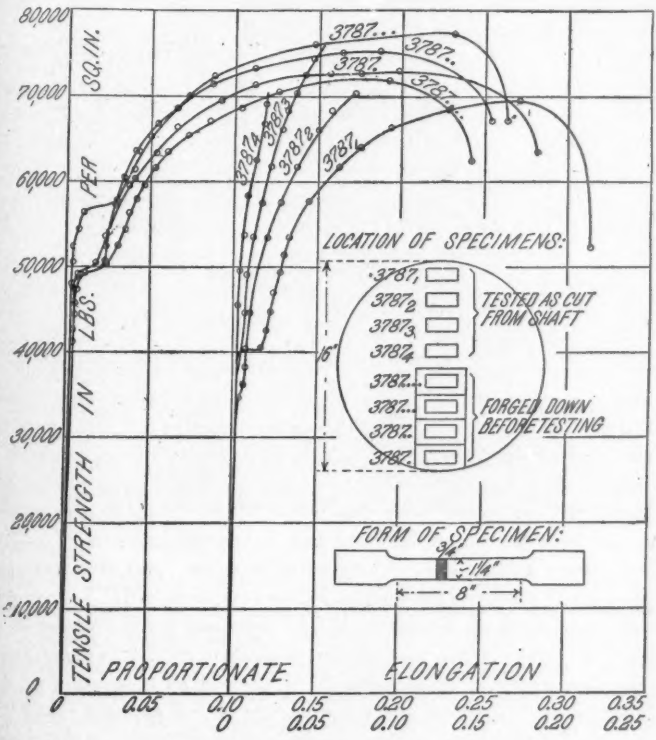

Fig. 7.

that well known concave end which is shown in the sketch, where the surface metal has been drawn away to such an extent as to leave cracks and sometimes large cavities in the center. What is shown at the end is simply an evidence of what has occurred all the way

through the shaft. Now, if we use a press in place of a hammer on a shaft of the same size, the pressure is applied very slowly, allowing time for the molecules of the metal to flow easily, and we then have the pressure passing all the way through the metal, and, as the center is hotter than the surface, and therefore softer, it will be squeezed out, and you will have the convex shape shown in Fig. 6 on the end of the shafts that have been hydraulically forged. By the press only can large shafts be obtained without defects formed during the process of forging.

Many so-called "steel forgings" are, even at the present day, turned out by forges which have not sufficient capacity to make them properly. Instead of working them down from ingots twice their diameter, as best practice dictates, they are compelled, because they have not hammers heavy enough to do the work, to use ingots which are only slightly in excess of the size of the finished forging. Such forgings are little better than steel castings and do not last long in service, and even when an ingot of proper size is insisted upon the surface metal only is affected, the center remaining in its original condition.

Fig. 7 is a diagram by Prof. Johnson, of St. Louis, showing a series of tests made at the Watertown Arsenal by the Government on a 16-inch shaft. This shaft was made for the United States cruiser "Dolphin" under a 10-ton hammer from a 30-inch steel ingot—which was very nearly the proper size—but broke after being in service a short time. In order to find out the cause of the break, test specimens were taken out of the metal at various distances between the surface and the center, specimens 3787_{1}—$_{2}$—$_{3}$ and $_{4}$ being taken first. Their form is given, and the tests are graphically shown in the curves. The test piece 3787_{1}, nearest the surface, showed an elongation of 21.4 per cent, and a contraction of 32.8 per cent; 3787_{2} showed an elongation of 7.2 per cent and a contraction of of 5.5 per cent; 3787_{3} showed an elongation of 4.9 (practically 5) per cent and a contraction of 5.2 per cent; and the one nearest the center showed an elongation of 2 per cent and a contraction of 1 per cent. In other words, the elongation varied, between the surface and the center, from 21.5 per cent to 2 per cent, and the contraction varied from 33 per cent to 1 per cent. You can see, therefore, that the center metal in this forging was practically unworked. In order to be certain that there was nothing in

the metal itself that would give this difference, they cut out from the opposite side specimens of a larger size and forged them down until they were of the same size as the first, or, to state it differently, they put work into the metal that ought to have been put into it when it was first forged, and, as a result, an average of 25 per cent elongation and 55 per cent contraction was obtained.

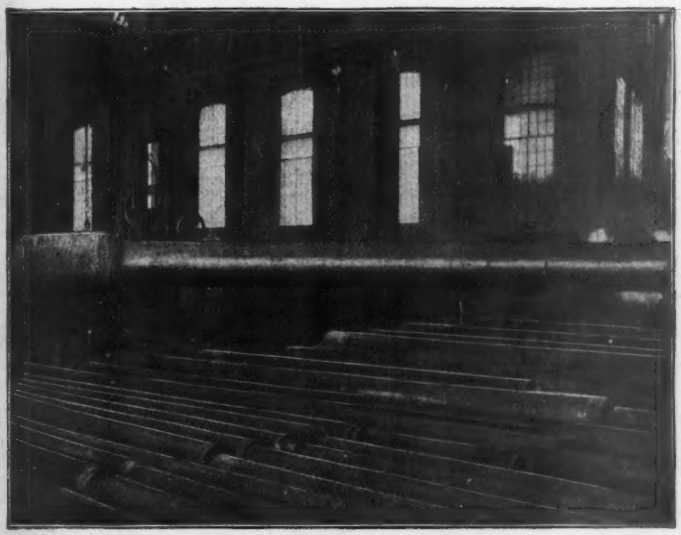

FIG. 8.

Fig. 8 represents the same ingot shown in Fig. 4, now being drawn out in the forging process. In this process of reduction in diameter and increase in length a great deal of work has been put into the metal. In order that the metal should be worked at the proper temperature, it is necessary to re-heat it a number of times, and every time a blow is made by the press the metal has been worked under conditions differing from those existing when the preceding blow was made, because it has cooled a little in the interval. As, therefore, no two parts of the forging when finished have been treated the same, it is natural to suppose that it is full of forging strains. It is also apt to have cooling strains in it, due to the fact that it has been re-heated from time to time in different

parts, as the forging process passes from one end of the piece to the other. To relieve these various strains all forgings are subjected to a final process called "annealing." This consists in put-

FIG. 9.

ting the forging into a furnace, starting a wood fire around it, and heating it to a definite temperature which experience teaches is best suited to the service to which the forging will eventually be

put; the fire is then allowed to die out and the furnace and forging to cool down slowly together. An annealed forging has its elastic limit somewhat reduced as compared to its tensile strength, but its ductility is increased considerably, as shown by its contraction and elongation in test pieces. The elastic limit of an annealed forging is invariably less than one-half of the tensile strength. By "elastic limit" I do not refer to the point usually determined by the drop of the beam in an ordinary testing machine, but rather to the carefully defined point obtained by more accurately determined methods, which is from two to ten thousand pounds lower.

All forgings should be annealed, and all specifications should be drawn so as to require that treatment. It is a process which is very seldom practiced in forges because not often required in specifications, and no one can tell whether a forging is annealed or not until after it has been in service for some time, when the cooling and forging strains develop and throw the piece out of shape.

In order to obtain from steel the very highest results there are still other processes to which it should be subjected after forging so as to develop its physical properties. One of these is that of "tempering."

Fig. 9 shows a tempering-plant. The forging is first re-heated to a definite temperature in a vertical gas furnace, then taken out and lowered suddenly into a bath of cold liquid, which may be oil or any other suitable fluid. The shaft in the picture is shown hanging from a traveling crane after having been withdrawn from the furnace, and is about to be lowered into the cold bath shown in the foreground. The forging must be subsequently annealed, as before, to relieve it of cooling strains. The hardening effect of the sudden cooling is accompanied by a "setting" of the amorphous condition brought about by the first heating, with the result that the irregular and often coarse crystalline condition existing after forging is broken up, and a uniform and finer grain ensues. By the subsequent annealing, strains are relieved and the hardening effect of sudden cooling is removed to a desired degree; at the same time the elastic limit is increased proportionately to the tensile strength, and a greater toughness is imparted to the metal, as shown by a higher elongation and contraction of area in test pieces.

In order to successfully temper a piece of steel, great care must be taken both in the process of re-heating it and also in cooling it in

the bath. During re-heating the surface metal is apt to expand away from the center and thus cause cracks in the latter, as previously explained; and in dropping it into the cold bath the surface metal is apt to contract on to the center to such an extent as to cause cracks in the former. In order, therefore, to successfully temper a forging it should be hollow. By taking out the centre, the piece can be re-heated without danger of cracking, because the center metal is absent and the heat gets into the interior and expands both it and the exterior together. Again, when immersing it in the cold bath, there being no solid center on which the surface metal is contracted, the danger of cracking the surface during the cooling process is in that way eliminated.

There are two ways of making a forging hollow. The ordinary way of getting rid of the center is simply to bore it out. After boring the forging is tempered, and thus the strength lost with the metal taken from the center is restored.

The hollow shafts which were first introduced into this country by Fried. Krupp of Germany have all been forged solid, bored, and oil-tempered. The high grade of that kind of work is well known.

Another way of getting rid of the center of large forgings is to *forge them hollow*. Any one who has not considered the subject carefully would naturally think that the first thing to do in making a hollow forging would be to cast a hollow ingot. I have already explained to you that there are various defects which occur in ingots, the most serious of which are segregation and piping, and that it is in the center and upper portion where those defects occur. Now, if we were to cast a hollow ingot, replacing the center metal by a solid core of fire-brick or similar material, we would have two cooling surfaces, one on the outside and one around the core, and would transfer the position of last cooling to an annular ring midway between these surfaces, where we would collect the piping and segregation. This would not do, because the metal there is what we are going to depend upon for the strength of our hollow forging, and we are therefore compelled to make our forging solid, as before, so as to collect the piping and segregation in the center and at the top, where we have added metal to the original ingot for the purpose.

Then, having cut off the top and thus gotten rid of what piping and segregation are there, we bore out the center, and so eliminate the piping and segregation at that point, what we have left being as

sound and homogeneous a piece of steel as can be obtained (Fig. 10.)

After the hole has been bored, the next step is to reheat the ingot, and, since the center is taken out, as before explained, this process is not as delicate a one as if the ingot were solid. The heat affects the interior equally with the exterior and the two expand together, thus avoiding the danger of cracking. When the ingot is reheated we put a steel mandrel through its hollow centre, and, subjecting the two to hydraulic pressure, force the metal down and out over

FIG. 10.

the mandrel (Fig 11). We thus practically insert into the forging an internal anvil and have therefore actually much less than one-half the amount of metal to work on that we would have had if the piece were solid. We have, for instance, in Fig. 12, a shaft 32 inches outside diameter with a 16-inch hole through it, leaving only 8 inches of metal to be worked upon between the press and the internal anvil.

A large number of hollow shafts of this type have been made for pumping engines in municipal and mining plants throughout the country, and similar shafts have also been made for engines in street

and elevated railway power-plants. These shafts have been about 28 inches outside diameter, 11 inches inside diameter, and twenty-five feet long. The Government requires that shafts for the navy shall be hollow, and this custom is being rapidly taken up in general marine practice.

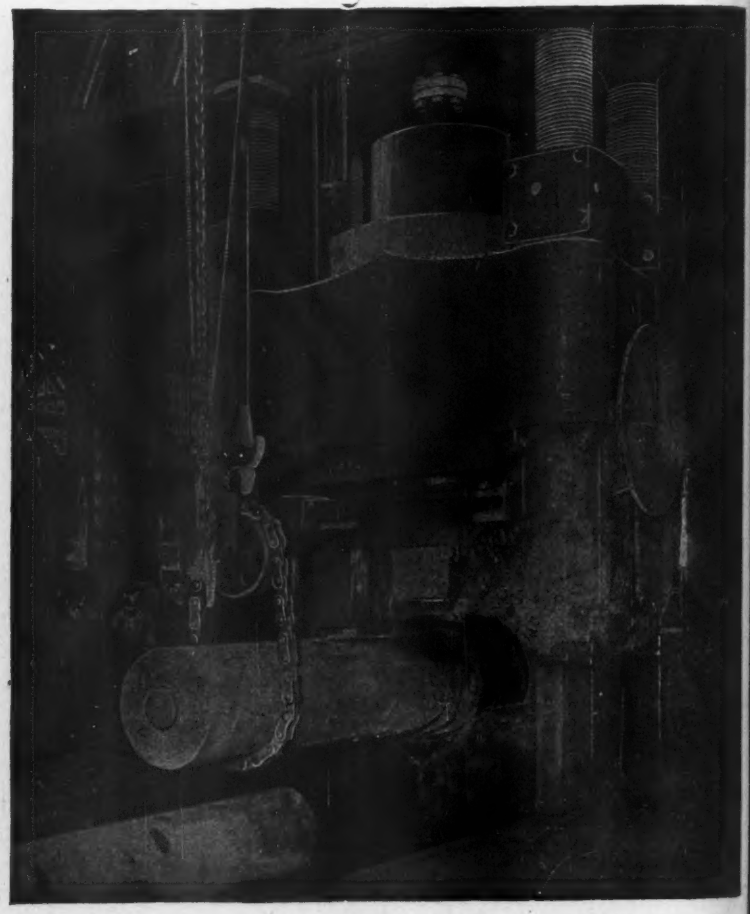

FIG. 11.

With the substitution in the trades of steel for wrought iron for engine and miscellaneous forgings, the tendency at first was to use a very mild, soft steel, approaching wrought iron in the ease with which it could be handled in the shop, especially in machining.

Mild steel, when of good quality, is superior to wrought iron in strength, toughness, homogeneity and freedom from danger of imperfect welds and porous spots enclosing slag, etc. Still it does not possess the very desirable quality of high elastic strength, combined with ductility or toughness, in as great a degree as can be obtained

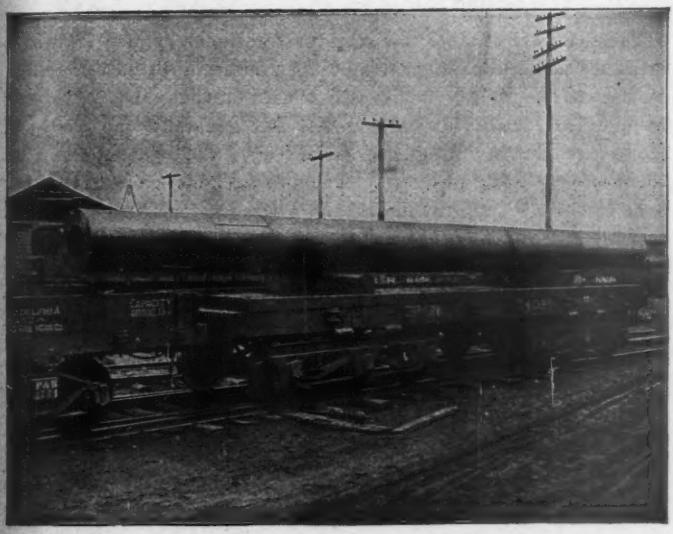

Fig. 12.

without danger in a harder steel, when proper precautions are taken in its manufacture.

It is only in recent years that high carbon steel has been found available for forging work. Fried. Krupp of Essen, Germany, was the leader in substituting his soft crucible steel for wrought iron, in heavy forgings. After 1870, soft open hearth steel became a more frequent substitute, with such success that, compared with wrought iron, the soft steel forgings made by well known English manufacturers soon attained a high reputation for their quality. It

was therefore natural that our government officials, when first issuing specifications for the heavy engine and shafting forgings required for the rebuilding of our navy, followed in the direction of the English practice, and called for a steel having a tensile strength of about 65,000 pounds per square inch, and a minimum elongation of about 28 per cent in four diameters. Today, however, we are called upon by our government to furnish a steel for the above purposes which will show a tensile strength of 80,000 pounds per square inch, an elastic limit of 50,000 pounds, and an average elongation of 25 per cent in four diameters.

The character of steel now used for crank-pins by many railroads furnishes a marked illustration of the practicability of using high carbon steels. When steel was first used in such pins, in place of wrought iron, a soft, low carbon steel was generally employed, and the failures due to "fatigue of metal" were almost as numerous as when wrought iron was used. The broken pins showed what has been called a "fracture in detail," a gradual parting of the steel extending inward all around the piece, undoubtedly produced by the working strains repeatedly approaching the low elastic limit of the soft steel. On substituting a steel with an elastic limit of 45,000 to 50,000 pounds per square inch, failures were greatly diminished without changing the diameter or shape of the pins.

"Fatigue tests" are made at the Watertown Arsenal by rotating rapidly a bar weighted in the center sufficiently to place the extreme fibres of the metal alternately in extension and compression.

These show the relative strength of steels of varying carbon to be about as follows:

.24	per cent	carbon	steel, annealed	229,300 rev.
.24	"	"	oil-tempered	348,000 "
.46	"	"	annealed	976,600 "
.46	"	"	oil-tempered	1,657,500 "
.66	"	"	annealed	3,689,000 "
.66	"	"	oil-tempered	4,223,600 "

The elastic limit, not the ultimate strength, is the proper point on which calculations should be made. This is the point which should not be exceeded at any time by the stresses which may be imposed upon metal. It is a point, however, very difficult to obtain

in ordinary practice, and requires delicate and special apparatus for its determination. It is usually considered to be the same as the "yield point" shown by the drop of the beam of the ordinary testing machine, but, when so determined, may be from 2,000 to 10,000 pounds too high.

This high carbon steel has been used largely by such representative pumping-engine builders as The Edward P. Allis Co., Fraser & Chalmers, H. R. Worthington, The Southwark Foundry & Machine Co.,The Lake Erie Engineering Co., Holly Mfg. Co., E. D. Leavitt and others. In general it can be stated that experience now shows that, where high duty is demanded of a forging, mild steel of a tensile strength of 60,000 pounds is not the best material to use, owing to its low elastic limit. The tendency is now toward the adoption of a higher carbon steel, followed by such treatment as will raise the elastic limit relatively to the ultimate strength.

Engine builders, although fully alive to the advantages of the use of high carbon steel, are deterred from its use by the fact that it is very tough, and therefore the cost of machining in the shops is high. In competition with his fellows the engine builder who uses the lower carbon steel can bid lower than he who uses the better grade. It is therefore to the interest of the water works engineer, who specifies what he wants, to insist upon his specifications being worded properly, so that all the bidders can base their calculations on the same grade of material.

The water works engineer does not want his engines composed of a weak and unreliable material merely because the engine builder finds it easier and cheaper to manipulate in shaping. He should follow the progress in steel making and insist upon getting the best he can afford to buy. The first cost may be a little greater, but he will save by getting a material much stronger and stiffer, and which will receive a higher polish. The lessening of friction of such parts alone will pay the difference in cost by the saving in fuel and lubrication.

Experience must teach the engineer what quality of steel is best suited for the various parts of his engines, and his judgment must determine whether he will use a high quality and decrease the size of his forgings, or a cheaper grade, putting in more metal and taking greater risk.

Although forgings can be made to fill a large variety of specifications, they can in general be divided into six classes, as follows:

1st, mild steel, annealed.
2nd, medium hard steel, annealed.
3rd, " " oil-tempered.
4th, nickel steel, annealed.
5th, " " oil-tempered No. 1.
6th, " " " No. 2.

Each of these classes is supposed to cover a series of grades of steel, varying in strength by several thousand pounds. In selecting the material for the forgings of an engine, and in drawing up the specifications therefor, the premise should not be omitted that "all forgings shall be made of open hearth steel," and that "they shall be carefully annealed after forging."

Large shafts and similar forgings, crank and cross-head pins, should be made of fluid compressed steel, and should be hydraulically forged, not hammered. Wherever practicable, an axial hole should be bored through shafts to insure absence of any internal defects. If shafts are oil-tempered, the hole can be made larger in diameter than if they are simply annealed, and where the hole is 7 inches in diameter and above, shafts can be forged hollow on a mandrel. A hollow-forged, oil-tempered shaft insures the highest attainable qualities, and can be especially recommended where the maximum strength with the greatest lightness is desired.

Where it is important that the quality specified should be obtained in the more important parts, physical tests of the forgings as delivered should be demanded. For such tests prolongations should be left on the end of forgings for the purpose of having test specimens cut from them after the forging and subsequent heat treatment has been completed. Such prolongations should receive no greater reduction than the forging at its largest part.

The following table shows the average physical qualities that should be obtained in forgings made of the several grades of steel mentioned, the test specimens being 2 inches long between measuring-points, $\frac{1}{2}$-inch in diameter, and cut from full size prolongations of the forgings after treatment; the elastic limit being determined not by the drop of the beam but by an electric micrometer.

Simple steel.	Tensile strength.	Elastic limit.	Extension percentage.	Contraction percentage.
1st, annealed,	58,000	28,000	28	55
2nd, "	80,000	37,000	23	45
3rd, oil-tempered, with axial hole,	80,000	45,000	25	50
Nickel Steel.				
4th, annealed,	80,000	45,000	23	45
5th, oil-tempered, with axial hole,	80,000	50,000	25	50
6th, oil-tempered, with axial hole,	90,000	60,000	22	50

Here are extracts from a few pump specifications picked up at random, from which it will be seen that they differ radically, although for about the same type of engine.

St. Louis Pumping-Engines. 1896.

"All steel forgings used in the construction shall be equal to forgings manufactured by The Bethlehem Iron Company, Bethlehem, Pa., and have a tensile strength of not less than 75,000 pounds per square inch of section, and show an elongation of 20 per cent in four diameters. Specimens to be taken from full sized forged prolongations after annealing. Shafts and crank-pins shall be hydraulic forged, fluid compressed steel. All steel forgings shall be properly annealed."

Chicago Pumping-Engines. 1896.

"All steel forgings used in shafts and crossheads shall have a tensile strength of not less than 65,000 pounds per square inch, and show an elongation of 25 per cent in 2 inches, and for connecting-rods a tensile strength of not less than 58,000 pounds per square inch, with an elongation of 28 per cent in 2 inches. Crank-pins shall have a tensile strength of not less than 75,000 pounds per square inch, with an elongation of 20 per cent in 2 inches. Specimens to be taken from full sized forged prolongations after annealing. All forgings shall be thoroughly annealed."

Boston Pumping-Engines. 1896.

"The crank-shaft and crank pins shall be of the best quality of forged fluid compressed steel.

"Steel forgings shall have a tensile strength of not less than 60,000 pounds per square inch of section, and show an elongation of not less than 20 per cent in 8 diameters. No steel shall be welded."

New Bedford Pumping-Engines. 1897.

"All forgings are to be of crucible or nickel steel; each piece to be oil-tempered. All steel is to have at least 50,000 pounds elastic limit per square inch, and 18 per cent elongation in 10 inches in test pieces 1 inch in diameter. Where forgings are shown to be bored out they may, if preferred by the contractor, be hollow forged instead of bored."

Buffalo Pumping-Engines. 1897.

Specifications read same as for the St. Louis pumping-engines above mentioned, and, in addition:

"The steel shall not contain more than .04 of 1 per cent of either sulphur or phosphorus, and not less than .40 of 1 per cent carbon."

Boston Pumping-Engines. 1897.

"The crank-shafts, cranks and crank pins, the piston, connecting, and plunger-rods, the crossheads and crosshead pins shall be made of fluid compressed or crucible steel of substantial proportions. Test pieces for forgings shall be cut from full size prolongations of forgings and shall receive the same treatment as forgings. Steel forgings for crank-shafts, cranks, crank-pins, crossheads, crosshead-pins, plunger, connecting, and piston-rods shall have an elastic limit of not less than 50,000 pounds per square inch and an elongation of not less than 18 per cent in 10 inches in a test piece 1 inch in diameter. Steel forgings shall be made without welds."

Chicago Pumping-Engines. 1897.

"All steel forgings used in the construction shall be equal to forgings manufactured by The Bethlehem Iron Co., Bethlehem, Pa., and have a tensile strength of not less than 65,000 pounds per square inch of section and show an elongation of 20 per cent in four diameters. Test specimens are to be taken from full sized forged prolongations after annealing. Shafts and crank-pins shall be hydraulic forged, fluid compressed steel. All steel forgings shall be thoroughly annealed."

Cincinnati Pumping-Engines. 1897.

"All steel must be of open hearth make, and shall contain not more than .05 of one per cent of phosphorus and not more than .03 of one per cent of sulphur. It shall be tough, ductile, of uniform texture and composition, and shall show a fracture of fine silky grain.

"Different grades of steel when tested in specimens of ½ square inch in sectional area, cut out of the finished piece, shall give the following results:

"Tensile stress without breaking, not less than 70,000 and not more than 80,000 pounds.

"Elongation in twelve diameters 20 per cent.

"Cold bending of specimen 180 degrees and setting flat on itself without sign of fracture.

"All steel forgings shall be hydraulic forged and properly annealed."

Pumps for Pope Manufacturing Company. 1895.

"The shafts are to be of fluid compressed open hearth steel, oil-tempered when built up, and properly annealed when not built up, having an elastic limit of 45,000 pounds, and 18 per cent elongation in 10 inches, in a test piece of 1 inch diameter."

It has been customary in the past for cities to have water supplied at moderate pressure throughout their systems of mains, and, in case of fire, etc., special engines take their supply at hydrants in the immediate locality of the fire. Owing, however, to the great drain on the mains at certain hours of the day, some cities have laid special systems of fire-mains through their streets leading to some accessible water front, patrolling which are fire-boats equipped with powerful pumping-engines. These engines supply water to the special mains at very high pressure.

These boats must be of light draft, and, necessarily, the pumps must be very light and strong, and the highest grade of steel must be used in their construction.

Centrifugal pumps, turbines and similar apparatus, which work on either solid or hollow shafts, should be supplied with a grade of steel suited to their requirements.

The power plant at Niagara, which comes in the above category, has specified for it steel having an elastic limit of 55,000 pounds, elongation of 23 per cent and contraction of area 50 per cent. Fig. 13 shows a specimen forging made for that plant.

I trust that I have been able to gather together for the members of this Association a few suggestions regarding forgings which may result in a saving of time and labor in searching for such information elsewhere.

I have endeavored to point out the direction in which improvement in forging processes is tending, and to offer suggestions by which the various grades of steel forgings can be obtained. If I

have succeeded in satisfying you that the day of wrought iron forgings has passed, and that the use of mild steel forgings is rapidly giving way to steel of higher carbon, I will feel that I have accomplished what I started out to perform.

FIG. 13,—Field ring for one of the 5000 H. P. Electric Generators at Niagara Falls. Outside Dia., 11 ft. 7⅞ in.; width, 4 ft. ¾ in.; thickness, 5¼ in.

NOTE.—Papers on this and analogous subjects have appeared in the Transactions of the Society of Naval Architects and Marine Engineers, Vol. I. 1893, by R. W. Davenport, and in Proceedings of the Engineers' Club of Philadelphia, Vol. XIII, No. 4, by A. L. Colby; also in Vol. XVII of the Transactions of the American Society of Mechanical Engineers by H. F. J. Porter.

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